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## CHAPTER FOUR

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# DRUG-INDUCED HALLUCINATIONS IN ANIMALS AND MAN

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The behavior of organisms is rich in examples of reactions to the pharmacological agents known as hallucinogens. Mice frequently exhibit head twitches that remind a human observer of someone trying to shake off some pesty insect or unpleasant feeling. Pigeons adopt a characteristic posture designating fear or else peck wildly at the air and retreat from what our human observer might describe as imaginary aggressors. Cats exhibit stereotypic approach and avoidance behaviors or play with what our observer might infer are imaginary mice or butterflies. The eye movements of monkeys seem to track imaginary insects, or the animals adopt a crouched posture with their head on their hands, a posture our human observer (by now running the risk of being labeled hallucinatory himself) finds vaguely reminiscent of Rodin's "Thinker" (Grunfeld and Edery, 1969). Men adopt similar behavioral postures or utilize verbal and other behaviors to describe their imaginary happenings.

Experiences with hallucinogens have puzzled and intrigued man for centuries. They have given him "sights" to see, "voices" to listen to, "thoughts" to ponder, and "altered states of consciousness" to explore. They have generated conditions that can only be described by such global and imprecise terms as ecstasy or madness. Some men feel closer to an understanding of themselves. Others feel closer to each other. Some feel a unity with all in their environment. Still others feel one with a universal being and might remark, like Baudelaire (1857) in "Poem of Hashish," "It will amaze no one that one last supreme thought comes bursting from the dreamers brain! 'I have become God!' " (p. 76). But each man finds himself alone. For when man perceives an hallucination he does so alone, in the privacy of his body.

Traditionally, man has attempted to understand hallucinations by analysis of overt verbal behaviors. Thus private (covert) experiences can achieve public status and can be subjected to the processes of consensual validation. Descriptive symbols such as words or pictures can be precisely defined, and their controlled use can be shared by others. In a sense, an individual's hallucination can be "seen" by



others. However, the task of analyzing such symbolic communication as language is not unlike the problem of analyzing the mouse's head twitches, the pigeon's pecks, or the monkey's eye movements. All these behaviors involve responses to perceived stimuli in the internal or external environment. Even though there are no objective stimuli in the case of hallucinations, we are still dealing with a valid type of inquiry into the behaviors of perceptual systems (cf. Hebb, 1968; Richardson, 1969; Bugelski, 1970; Horowitz, 1970).

This chapter attempts to describe such behaviors and to outline the methods used in their experimental analysis. Part I discusses the behavioral responses of infrahuman species to hallucinogens; it includes observations in the field and laboratory as well as experimental paradigms that have been modestly successful in understanding hallucinogen-induced changes in animal perception. Part II treats the nature of drug-induced visual imagery in man; it includes sections on the definition and phenomenology of drug-induced hallucinations as well as the history of experimentation in this area. In addition, a series of studies on drug-induced visual imagery in man is presented. A theoretical model to account for the findings of these studies is developed in Part III.

Since the title of this chapter raises a variety of empirical questions, it is appropriate to define the limits of the present discussion. Not only are hallucinations responses to pharmacological stimuli, they may also be considered stimulus events of which organisms become "aware" and to which they subsequently respond. In this chapter, however, we are primarily concerned with hallucinations functioning as stimulus events, not with pharmacological stimuli or their mechanisms of action (see reviews by Weil-Malherbe and Szara, 1971; Brawley and Duffield, 1972).

It should also be noted that the chapter does not address itself to the variety of sensory modalities in which hallucinations may occur. Since man's behavior is primarily visually mediated, we have chosen the visual modality for study. The responses to the visual imagery of hallucinations can be surprisingly realistic. Many of our subjects under the influence of *Cannabis* would have thought that they were watching a motion picture if they had not known they were in a completely dark chamber. Equally remarkable reactions occur to the nonvisual imagery of hallucinations (e.g., auditory, olfactory, or kinesthetic imagery). Imagery often occurs simultaneously in two or more modalities and is referred to as synesthesia. One mescaline-treated subject reported a visual-algesic synesthesia in response to being pricked with a sharp instrument: "I've got concentric circles like round the top of a radio mast. If you touch me, jagged things shoot up; little-sort-of-jagged things, from the centre" (McKellar, 1957, p. 63). Taken together, these responses can constitute the "psychedelic" or "consciousness-expanding" experiences commonly associated with drug-induced hallucinations. The present chapter does not attempt to comment on these phenomena. However, the possibility of complex multimodal hallucinations existing in the drug state can temper an initial excitement and perplexity about reactions in the single modality of vision.

## PART I: ANIMALS

It is well known that *Homo sapiens* voluntarily learns to self-administer psychoactive drugs, and among the many drugs used in this way by man are the hal-



lucinogens. Indeed, it is a traditional, albeit tacit, assumption of psychopharmacological thinking that *Homo sapiens* is the only species that will self-administer hallucinogens without additional reinforcement. It is often further assumed that the human use of hallucinogens is both a necessary and sufficient condition to determine whether a given drug produces hallucinations and thus can be classified as a true hallucinogen. Such assumptions have led investigators to restrict the use of infrahuman species to the formulation of biochemical and physiological models of hallucinogen action since, a priori, these animals neither self-administer hallucinogens nor report private events such as hallucinations. The recent increases in the nonmedical use of these drugs in Western societies, together with the interest in hallucinatory experiences as reflected in current literature, have made these assumptions more explicit, leading to a myriad of studies and analyses of hallucinogen-induced behavior in man. The resulting research has generated a number of hypotheses regarding hallucinations produced by drugs, but these are not always practically, morally, or legally verifiable by systematic empirical study. The urgent need for a firmly grounded theory of hallucinogens and hallucinations prompts a reevaluation of the basic assumptions just stated.

This part of the chapter examines these assumptions in light of recent ethological and laboratory findings, encompassing field and laboratory observations and studies. The discussion is guided by existing observations and data and is fostered by some speculation and inference. The observations, however crude and uncontrolled, provide valuable information on animal reactions to hallucinogens. Some allowance for speculation and inference must be made, since the search for infrahuman reactions to hallucinogens may uncover new areas and models for the study of hallucinations in man. Such infrahuman models would have the advantage over others of greater experimental control without the addition of "untestable mentalistic constructs" (Schuster and Thompson, 1969).

### FIELD OBSERVATIONS OF HALLUCINOGEN-INDUCED BEHAVIOR

We have few reliable ethological reports of animal reactions to psychoactive drugs in general, and hallucinogens in particular, since many of the observations are based on mythology and folklore (Siegel, 1973a). For example, many anthropologists believe that primitive people may have learned the rudiments of medicine by observing which plants were used by animals suffering from wounds, fever, or infection. In India, folklore maintains that the mongoose, when bitten by a cobra, retires to the jungle to look for a plant known as mungo root (*Ophiorrhiza mungos*), which it eats as an antidote to the venom. Mongooses have also been reported to pretreat themselves by rubbing the root over the parts of the body that the snake is likely to attack. This treatment usually results in a "drugged sleep" from which the animal quickly recovers (Hinton and Dunn, 1967). Although the mungo root naturally enough evolved as a native charm against snake bites, and infusion teas of the root were later used for treatment of gonorrhea and scabies, there has been no evidence to indicate that it is effective against snake venom. Many anthropologists also believe that early man learned about drugs by observing the effects of accidental self-administrations in animals. The legendary discovery of coffee purportedly occurred around 900 A.D. An Abyssinian tending his herd of goats noticed that his animals became abnormally frisky after eating the



bright red fruit of a tree: the substance was later isolated and identified as coffee (Taylor, 1965). Similarly, Pope (1969) suggests that *Tabernanthe iboga*, an hallucinogenic plant containing ibogaine, may have been discovered by boars, porcupines, and gorillas in the jungles of Gabon and the Northern Congo in Africa: "Several accounts mention that the natives saw boars dig up and eat the roots of the plant, only to go into a wild frenzy, jumping around and perhaps fleeing from frightening visions" (p. 174). The folklore of several other peoples is replete with equally intriguing and speculative notions. In Czechoslovakia, peasant stories tell that man learned of the stimulant properties of *Cannabis* by observing the abnormally high jumps of grasshoppers that fed on local varieties of this plant. Some Indian groups in Central Mexico abstain from *Cannabis* use because of a long-held belief it is "food fit only for animals," since local monkeys continually raid and feed on the young plants.

There are other reports in which it is only speculated that animals that regularly ingest toxins that cause hallucinations in man show the same psychoactive effects. For example, it is claimed that domesticated horses and cattle develop "cravings" for and "addictions" to a variety of poisonous plants, many of which cause psychoactive effects in man (Forsyth, 1954). Domesticated dogs, which help herd cows in the Hawaiian Islands, have been observed to become abnormally playful after ingesting the psilocybin mushrooms that grow in the pastures (Siegel, unpublished observation). Some mongooses in the West Indies and the Hawaiian Islands ingest mostly *Bufo marinus* toads, which contain the hallucinogen bufotenine. This phenomenon is something of a mystery, since other toads as well as other natural prey are more abundant in these regions. Although it is not known whether there are psychoactive effects resulting from such ingestions, the mongoose is considered by some natives to be a drug addict. It goes out of its way to ingest a variety of psychoactive compounds and poisons, including the poison bulb of scorpions and the sting, "which it seems to consider a *bonne bouche*" (Hinton and Dunn, 1967, p. 20). Birds in the Hawaiian Islands have been observed to feed on San Pedro cactus (*Trichocereus pachanoi*)—which contains mescaline—and local people claim that this affects the birds' disposition and flight patterns (Siegel, unpublished observation). Bees are naturally attracted to male *Cannabis* plants, and their honey, when collected and assayed, has been shown to contain traces of tetrahydrocannabinol (THC) (Mendell, 1969). Some writers in the "underground press" have enjoyed speculating about "stoned bees"; however, there are no studies of individual bees showing psychoactive effects or repeating that particular pattern of behavior. The insect *Oxythris canabensis* is a natural enemy of *Cannabis* plants in Rumania but, again, there are no behavioral studies on the effect of this relationship. Similarly, it is rumored that the natural predators of the South Pacific goatfish may become intoxicated after eating their prey. Such stories are probably based on the "fantastic nightmares" and hallucinations produced in man by ingestion of this fish (Halstead, 1965).

Many field reports, like some just cited, are based on single accidental administrations of the drugs and lack the support of controlled observational or laboratory studies. There are occasional journalistic reports of animals self-administering hallucinogens, as well as several studies of accidental *Cannabis* poisoning in grazing horses and mules and in domesticated dogs (e.g., Clarke et al., 1971). Even when such accidental ingestion does not result in death, there is only scant



evidence that the animals are "intoxicated" and no firm evidence that the behavior is "hallucinatory." The most common instance of such accidents is found in the etiology of locoweed disease, which affects cattle, horses, and sheep on the Great Plains of the western United States and is caused by ingestion of locoweed (*Astragalus*). Locoweed (which literally means cracked brain) contains selenium, which is absorbed from the surrounding soil, and the disease resulting from its ingestion is characterized by paresis, ataxia, dullness, and a tendency of the animals to isolate themselves from social groupings.

Although alcohol is not classified as an hallucinogen, there are a number of reports illustrating the hallucinosis that results from chronic alcohol ingestion and/or subsequent delirium tremens (e.g., Clarke, 1878; Brinkmann, 1972). Both Carrington (1959) and Sikes (1971) review evidence suggesting that African elephants, like man, have a "passion" for alcohol. The usually graceful movements of these animals are marked by awkward and inappropriate behaviors after ingestion of this substance. Drummond (1875) described this phenomenon:

They [the elephants] frequent, as I have mentioned, the country from the Pongolo northward, during the summer season, retiring to their fortresses in the interior at the approach of winter. The time of their arrival is simultaneous with the ripening of the umganu-tree, of which they are passionately fond, and doubtless come in search of. This fruit is capable of being made into a strong intoxicating drink, and the elephants after eating it become quite tipsy, staggering about, playing huge antics, screaming so as to be heard miles off, and not seldom having tremendous fights (in Carrington, 1959, p. 68).

Several members of the cat family repeatedly self-administer catnip (*Nepeta cataria*). Catnip, a member of the mint family, has been used by man as an hallucinogen with effects similar to those of *Cannabis* (Jackson and Reed, 1969), probably caused by the nepetalactone oils in the plant. In cats, the response is characterized by sniffing, licking, chewing with head shaking, chin and cheek rubbing, and headover and body rolls accompanied by some salivation (Todd, 1963). Hatch (1972) described frequent signs of apparent hallucinations such as "phantom butterflies" above the cat and "phantom mice" in the cat's cage as inferred from the observed behavior.

The reindeer of the Asian forest and tundra regions are frequently afflicted by insects in their nostrils. These states are marked by wild and frenzied behaviors, and the reindeer run aimlessly away from the herd. The reindeer and the native Chukchki people ingest *Amanita muscaria* mushrooms, which contain the hallucinogens muscimol and ibotenic acid. The people's behavior is characterized by elation, sedation, colored visions, and hallucinations. Wasson (1968) summarizes observational evidence suggesting that the reindeer may also be "hallucinating" since their behavior is described as "drunk," "intoxicated," "noisy," abnormally aggressive, and similar in many ways to the insect-induced state.

Hempseeds (*Cannabis sativa*) and avians have enjoyed a long historical association. Many birds, including the pigeon (*Columba livia*), eat hempseeds, which until recently were available in commercial bird feeds. The pigeon has a marked behavioral preference for these seeds, and it has been reported that wild mourning doves and pheasants in areas of Illinois and Iowa also eat them. Hempseeds can contain small quantities of cannabinoids, including tetrahydrocannabinol. In addition, they nearly always contain some green gummy calyx, which probably



contains additional amounts of cannabinoids. Levi (1957) discusses the historical uses of hempseed as a source of pigeon food and summarizes evidence from breeders, who refer to the seed as "pigeon candy" and use it as a delicacy and a stimulant for their birds. The following account illustrates the behavioral effects:

[Hempseed] feeding has a decided beneficial psychological effect upon the bird's happiness. Pigeons fed sparingly with a little hemp in the middle of the day during the moulting season take a new interest in life which is almost inconceivable. In general, scattering any feed upon the ground of the flypen is dangerous because of possible contamination and infection. An exception to this rule is the feeding of hempseed in such fashion. When some hemp is fed out on the dry ground of the flypen, every bird comes out for its share. The avidity with which the seed is devoured has to be seen to be believed. Even after the portion of hemp has been consumed, many of the birds may be seen for hours diligently searching for a possible additional grain. . . . It [hempseed] is of great assistance in taming birds and in training them for shows, as all fears seem to be set aside when they know that hempseed is being offered (p. 499).

All these observations must be accepted with caution since, as a rule, infrahuman species do not readily self-administer hallucinogens in natural states. Even under laboratory conditions, only a handful of investigators have been successful in training animals to self-administer hallucinogens, and then only to obtain additional food or water reward (e.g., Zimmerberg et al., 1971). Recently, however, Pickens and Thompson (1972) have reported that one monkey in their laboratory self-administered hashish on an operant schedule without additional reinforcement.

One explanation for these findings that hallucinogens are not readily self-administered by animals is that such treatment involves a punishing or negative reinforcing component. Indeed, conditioned taste aversion tests in rats have shown that high doses of mescaline and tetrahydrocannabinol are unpleasant and serve as a punishment in this situation. The classic paradigm of this test involves a novel taste, such as sodium saccharin, that is paired with novel gustatory cues associated with noxious internal states, such as produced by emetic agents like lithium chloride or X-irradiation (Garcia and Ervin, 1968). Usually, aversion to the novel gustatory cues becomes associated with (or conditioned to) the novel taste, and animals will subsequently avoid instances of the taste alone. Corcoran (1973) paired saccharin with intraperitoneal injections of hashish extract in rats. Subsequently, the novel saccharin taste was avoided by water-deprived rats offered a solution with that taste. One could object to Corcoran's conclusion that this indicates hashish was unpleasant and punishing for the rat on the grounds that such drug experiences can be aversive for pharmacologically naïve animals, as they often are for humans. These animals might experience unpleasant disorientation produced by the very novelty of the drug state itself. Repeated drug treatments might have the effect of decreasing novelty and reducing aversion. Corcoran's demonstration that three saccharin-hashish pairings did not significantly affect the strength of the aversions may not have been sufficient treatment to allow the animal to become pharmacologically experienced or tolerant. More recently, however, Corcoran and Amit (1974) have shown that rats are generally reluctant to self-administer hashish orally. This reluctance is not affected by several experimental procedures that can increase their intake of other drugs.



Nevertheless, hallucinogen-induced aversive effects have been compared with drug-induced "illness" or "sickness" (Elsmore and Fletcher, 1972). It has even been argued that such aversiveness supports the notion that the naturally occurring plant hallucinogens are evolutionarily justified in terms of the maladaptive effects they could have on herbivores (Eisner and Halpern, 1971). For example, the plant henbane (*Hyoscyamus niger*) contains the active principles hyoscyamine, hyoscine, and atropine, and it causes hallucinations in man. In addition, henbane has a strong nauseating odor and taste that animals and men actively avoid, ingesting the plant only by accident.

## LABORATORY OBSERVATIONS OF HALLUCINOGEN-INDUCED BEHAVIOR

The behavioral consequences of hallucinogen treatment in animals can vary with a number of interactions between behavioral and pharmacological systems (see reviews by Brown, 1967; Weckowicz, 1967). The description of these interactions requires information about concomitant variations between the parameters of the behaviors and of the drugs. Information about the behaviors should be specific with respect to species variability, type of behavior, past behavioral history, and other factors. Information about the drugs should be specific with respect to dose, time, dose order, route of administration, localization of the site of drug action, absorption and distribution in the body, and biological fate, to name just a few items. Such variables can be further modified by environmental set and setting. The resultant behavior cannot be fully understood unless all these underlying variables are so specified. Furthermore, recent advances in neurochemistry suggest that many drug effects on behavior are mediated by neurochemical events and that these relationships are reciprocal in that changes in one may affect the state of the other. If all these possible combinations and permutations appear to be hopelessly confounded, it should simply caution us in making any generalizations about hallucinogen-induced behavior in animals. A full understanding of these interactions is restricted by the limits of present empirical data, but the presence of such intricacies should make us suspicious of studies that simplify the behaviors with terms such as "hallucinatory." For example, Klüver (1933) reported that mescaline produced in monkeys a characteristic "oral syndrome" that was marked by lip, tongue, and jaw movements coupled with licking and chewing. The syndrome was frequently accompanied by the monkey's wiping, touching, and scratching various parts of its own body. The presence of a similar mescaline-induced oral syndrome in man prompted Klüver (1966) to suggest the possibility of somatosensory hallucinations, although he cautioned that observations of such behaviors do not permit reliable inferences about their sensory concomitants. Similarly, Dement and his co-workers (1970) have argued that the demonstration of drug-induced hallucinations in an animal depends entirely on what one is willing to infer from the associated behavior of that animal. Indeed, these authors note that "it is also obvious that the behavior alone can be somewhat misleading. For example, the response of a decerebrate cat to pinching the tail invariably convinces at least one student that [the animal] is in great pain" (p. 346).

Nonetheless, there is a certain utility in discussing broad areas of behavior and the ways in which drugs may affect them. Such an analysis permits us to focus on



categories directly relevant to man's hallucinatory behavior. Behavior is usually defined as activity of an organism observable by the organism itself or other organisms. Thus one of the first approaches that might be valuable to man is the observation of hallucinogen-induced behavior in other species under laboratory conditions.

**Mice.** Several uncontrolled studies have noted interesting patterns of hallucinogen-induced behavior in mice. Woolley (1955) reported that mice injected with LSD (100 mg/kg, i.p.) exhibited headshaking, piloerection, and behavioral postures consisting of spread forelegs and backward locomotion. This author compared the latter behavior with that of mice resisting movement down an inclined plane and hastily concluded that the LSD-treated animals were hallucinating sliding down an inclined surface or resisting and backing away from an uncertain situation. Grainer-Doyeux (1956) gave mice and rats Nopo powder prepared from the seeds of *Anadenanthera peregrina*, an hallucinogen used by Guahibo Indians. The mice exhibited increased grooming behavior, head twitching, and nasal scratching, and appeared to be "drunk" and "hallucinatory" as inferred from their locomotor activity and visual orienting responses. Fellows and Cook (1957) noted that mescaline (20–100 mg/kg) given orally to mice increased the frequency of scratching and grooming postures and cited such behavior as evidence for cutaneous paresthesias (hallucinations). Haley (1957) found that intracerebral injections of LSD (5 mg) in mice produced hyperexcitability to visual and auditory stimuli as well as direct aggressive attacks on any object placed in front of the animals. Intracerebral injection of mescaline (10 mg) produced similar effects, coupled with paroxysmal ear scratching. Several other investigators have noticed similar hallucinogen-induced responses in mice, and these always include head twitching (e.g., Corne and Pickering, 1967; Siegel and Poole, 1969; Siegel and Jarvik, 1971; Kulkarni, 1973).

The drug-induced head twitch in mice has been described as resembling a strong pinna reflex involving lateral movement of the entire head without observable tactile stimulation (Corne and Pickering, 1967). In subjective terms, the animal is shaking its head as if to escape from an "apparently" aversive stimulus. As already noted, the concomitant increases in both frequency and duration of grooming postures, such as paroxysmal ear scratching, have even been cited as evidence for "cutaneous hallucinations." A device recently developed to record and measure these twitches (Siegel et al., 1972) consists of a magnetic head unit, worn chronically by the mice and allowing for free movement in the cage. When a mouse twitched its head, lateral movement of the unit produced a change in its adjacent magnetic field which was amplified and channeled to digital and analog recorders. Treatment with hallucinogens induced significant changes in head-twitch rates when compared with predrug periods or treatment with nonhallucinogens. In one series of experiments, Siegel and Jarvik (1972) attempted to rank and compare various hallucinogens by determining the minimum effective dose necessary to induce head twitches in at least 50% of the population (MED-50). These MED-50s, determined in groups of 15 to 20 mice, were found to be 15 mg/kg for bufotenine, 0.05 mg/kg for LSD, 25 mg/kg for mescaline, and 10 mg/kg for ketamine. Figure 1 shows mean head-twitch rates during pre- and postdrug periods for various mescaline doses. In Fig. 2 the hallucinogens



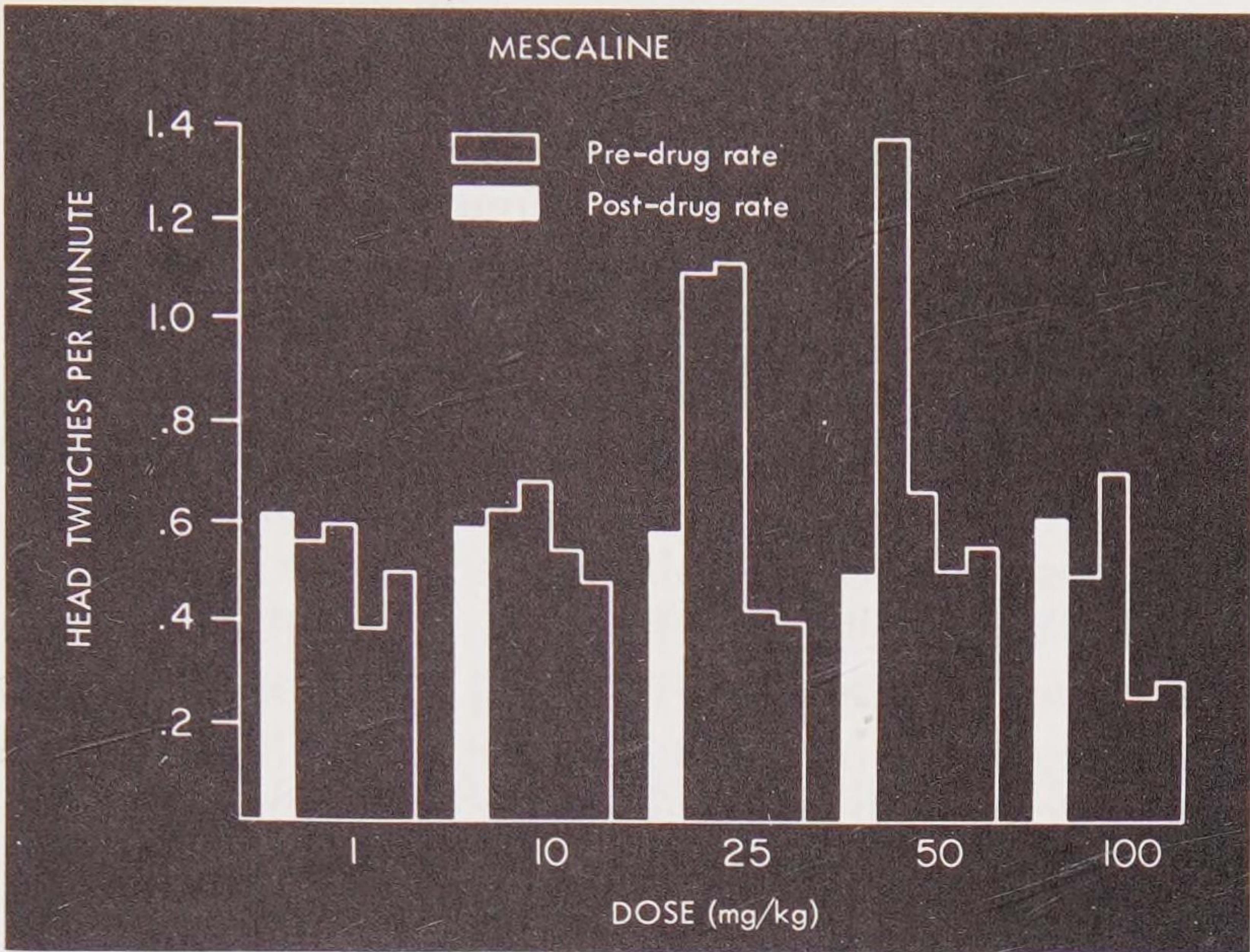


**Figure 1** Mean head-twitch rates per minute for groups of mice in mescaline conditions. Predrug rates calculated from the 30-minute baseline recording before drug treatment; postdrug rates calculated in consecutive blocks (represented by steps on the histograms) of 30-minutes from the two-hour recording following treatment. Each dose level represents a group of 20 animals.

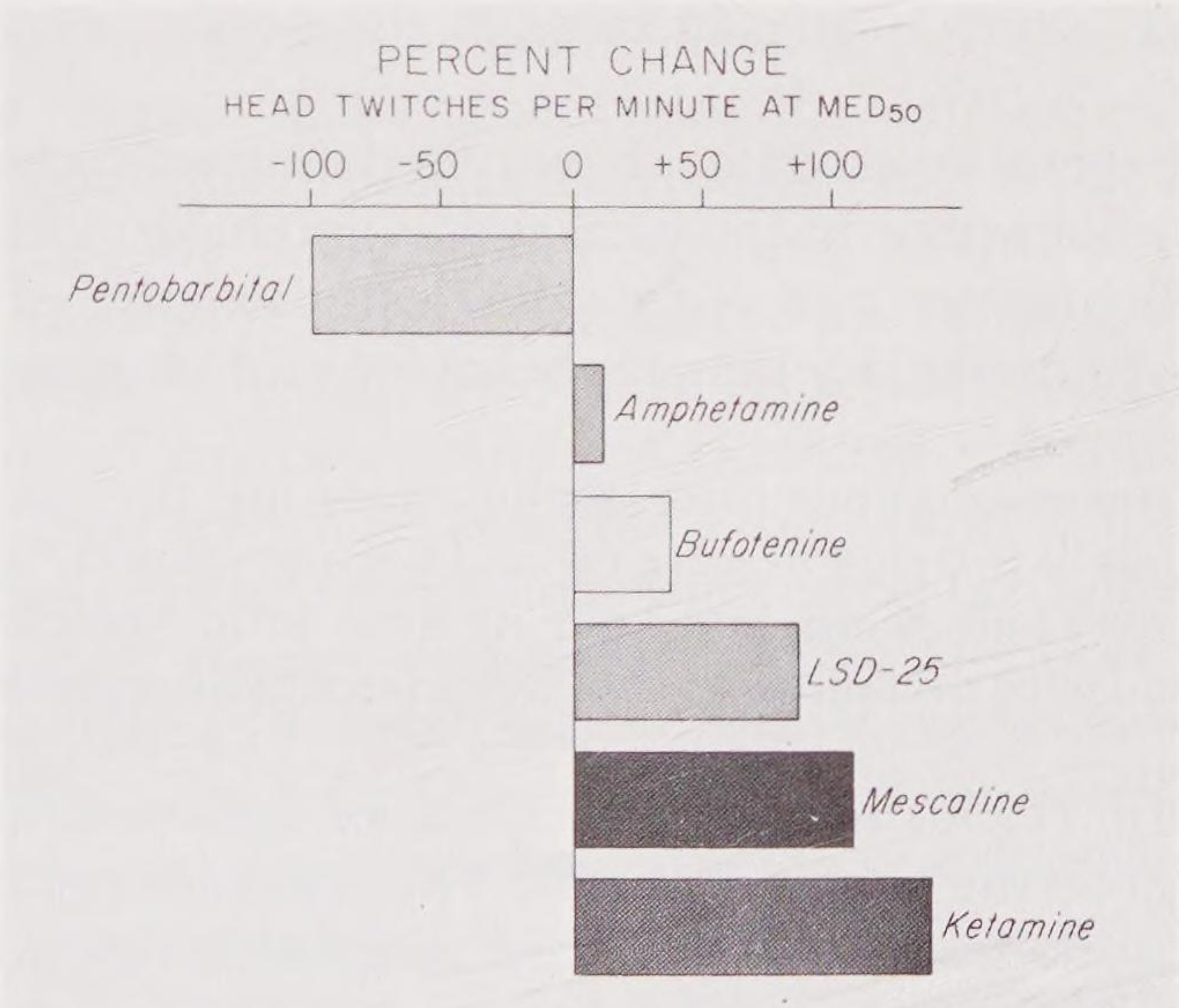


**Figure 2** Mean percent change in head-twitch rates per minute at MED-50 levels for each drug. Each histogram represents separate groups of 20 mice each.

bufotenine, LSD, mescaline, and ketamine are arranged in ascending order; interestingly, this continuum is virtually identical to that depicting the degree of central nervous system excitation induced by the same agents in cat brain (see Winters, this volume). As expected, pentobarbital suppressed head twitches as well as general activity, and *d*-amphetamine induced maximal twitching at 5 mg/kg (but this change was not significant). Although we still do not know whether



these head twitches represent hallucinations, the dosages necessary to induce them are highly correlated with doses that produce reports of hallucinations in man (Corne and Pickering, 1967). In addition, prolonged solitary confinement produces identical head-twitch responses in mice (Keller and Umbreit, 1956) as well as hallucinations in man (Zuckerman and Cohen, 1964).

Recently Boulton and Handley (1973) have demonstrated that the head twitch is highly dependent on sensory input from the pinna. These investigators infiltrated the local anesthetic lignocaine around the base of mice's ears, and this was highly effective in antagonizing both the head-twitch response and the pinna reflex. Increasing sensory input from the pinna with the irritant xylene increased a drug-induced head-twitch response. In these studies, the authors induced head twitching with 5-hydroxytryptophan (5-HTP). This compound has not been shown to be hallucinogenic in man, but Corne et al. (1963) have argued that this is simply because a large enough dose has not yet been administered. Nonetheless, 5-HTP-induced head twitching has been correlated with rises in 5-hydroxytryptamine (5-HT) levels in the brain stem. Furthermore, it has been hypothesized that hallucinogens such as LSD act by mimicking the central actions of 5-HT (Aghajanian, 1972), which may result in abolition of the sensory filtering mechanisms in the reticular formation (Bradley and Key, 1958). Boulton and Handley's study shows that the 5-HTP head twitch is highly dependent on sensory input from the pinna and that "this response could be due to the perception of previously subliminal stimuli from the pinna region" (p. 213) if not hallucinations per se. These authors also found that isolation greatly diminished the head-twitch response to 5-HTP, which argues in favor of the notion just advanced.

**Cats and Dogs.** Several investigators have noted unusual patterns of behavior in cats treated with various pharmacological agents and have labeled such behaviors "hallucinatory." Schneider and Sigg (1957) studied the effects of ibogaine hydrochloride (2–10 mg/kg, i.v.) on cat behavior and observed that:

Usually the animal remained in one place, slightly shivering, the tail out-stretched, while making hissing sounds as if trying to scare off an imaginary object. Often the cat tried to move toward a corner, hide there, and bury its head in it. Sometimes the animal approached a corner and tried to climb up the walls, apparently attempting an escape (p. 766).

Sturtevant and Drill (1956) studied the effects of intraventricular injections of mescaline (1–3 mg) on the behavior of cats. The resultant syndrome consisted of continuous yowling noises as well as severe autonomic reactions including mydriasis, tachypnea, and catatonia. The cats appeared to lose their aggressiveness toward mice, "fondling" them instead of attacking. Conversely, Norton and Tamburro (1958) found that LSD increased aggression and hostility in cats and decreased their "sociability."

In another study, cats treated with LSD (25–100 mg) exhibited head shaking and staring while adopting a "kangaroo" posture consisting of sprawled legs with claws and tail extended (Adey et al., 1962). Similar abnormal postures and inappropriate behaviors have been observed in cats following treatment with LSD, mescaline, nitrous oxide, diethyl ether, ketamine, tiletamine hydrochloride, and a diazepam derivative (Winters and Wallach, 1970; Winters et al., 1972; Massopust et al., 1973). The "kangaroo" posture is also seen in dogs treated with ibogaine



(Lambert and Heckel, 1901) or mescaline (Hardman et al., 1973). In addition, the dogs assume other bizarre postures and manifest convulsions with apparent hallucinations:

The convulsive episodes are preceded and followed by barking, yelping, and apparent hallucinations. The dog usually exhibits marked mydriasis and runs wildly about the room bumping into walls and furniture. The dog also appears to be apprehensive, frightened and disoriented; barking or snarling at inanimate objects is noted frequently. The 7 analogs of mescaline produce similar qualitative effects in the dog with adequate doses (Hardman et al., 1973, p. 304).

Harmin and diethyltryptamine (DET) also induce apparent hallucinations in dogs (Sai-Halász and Endröczy, 1959; Gershon and Lang, 1962):

The whole behaviour was similar to that observed in humans in a hallucinatory state: the dog was staring at a point in front of it, suddenly jumped back, then went on staring again, etc. (Sai-Halász and Endröczy, 1959, p. 405).

Sudilovsky et al. (in press) described amphetamine-induced stereotypy in cats as including minutia-searching patterns involving head and neck movements and a "fly-catching movement" comprised of a sudden swing of the head with rapid extrusion of the tongue. They observed "alternating flexion and extension of the paw as if the cat were attempting to shake something off of it," as well as signs of hallucinations such as "striking at nonexistent objects in the air, retreating movements or eluding jumps." And even though the cats often were frozen in catatonic postures following chronic amphetamine intoxication, abrupt orienting movements "towards a real or 'hallucinated' stimulus were often observed . . . not infrequently a cat would jump back and turn vigorously to one side in response to a nonexistent apparently hallucinatory stimulus" (Ellinwood et al., 1973, pp. 1089-1090). It is interesting to note that severe psychogenic shock can produce similar behavior. Mitchell (1953) noted that after serious flooding of a coastal area of Britain, six out of ten cats examined exhibited continuous and repeated attempts to catch imaginary objects on the ground and in the air.

The effects of hallucinogenic amphetamines on cat behavior as compared with the behavior of other species were examined by Florio et al. (1972). These investigators found that 2, 5-dimethoxy-4-methyl-amphetamine (DOM or STP) induced EEG excitation in rats, as well as backward locomotion, head nodding, and a stereotypic pattern of behavior known as the "wet dog syndrome" (a shaking of the body, like a wet dog trying to dry itself). Such excitation and wet dog shakes were also induced in rats by *d*, 1-3-4-5 methylenedioxy-methoxy-amphetamine (MMDA). DOM produced searching and exploration in rabbits, alternating with periods of stupor and catatonia. Another hallucinogenic amphetamine, *d*, 1-4-methoxyamphetamine (PMA) produced excitation and backward locomotion in rabbits. As the authors tested animals further up the phylogenetic scale, these amphetamine-induced behavioral changes appeared even more purposeful. In cats, DOM (0.25 mg/kg) "gave rise to characteristic changes in behavior which we have designated as 'hallucinatory': striking at imaginary objects in the air, sometimes exhibiting bizarre postures, staring intently at a corner of the cage, and shaking the head" (Florio et al., 1972, p. 406).

Analyzing videotape records of cats, Dement et al. (1970) found that they



responded to internally generated brain excitation (pontine-geniculo-occipital or PGO spikes) with orienting responses including head and eye searching movements. These behaviors are similar to those seen in cats treated with parachlorophenylalanine (PCPA), a selective depletor of brain serotonin (Dement et al., 1969). It is tempting to label behaviors in both cases "hallucinatory," since the animals "looked around" for no apparent reason, but Dement and his colleagues present one of the most reasoned and cautious interpretations of these phenomena in the literature:

Our current feeling is that the PGO spike activity does not instigate fullblown hallucinations (waking dream images) in the cat. In the first place, the behavior is *not* ordinarily accompanied by signs of emotion—anger, fear, or affection. In the second place, the animals rarely exhibit visual fixation—rather, the behavior more properly suggests alerting, searching, and/or expectancy. The best inference is that a burst of PGO spikes in the waking state is perceived by the cat as a barrage of simple stimuli, like knocking on a door or flashing a light. Occasionally, the cat does respond to waking spike bursts with behavior that could be termed hallucinatory. However, we are willing to stipulate that although PGO spikes may be a necessary ingredient in the production of hallucinations, they are not sufficient, and that the ability to respond to their occurrence with the elaboration of complex imagery might require more brain than the cat possesses (Dement et al., 1969, pp. 793–794).

**Monkeys.** Although Dement and his colleagues were appropriately cautious about labeling PCPA-treated cats "hallucinatory," the dramatic effects of PCPA treatment in two rhesus monkeys convinced them that the resultant behavior was indeed hallucinatory:

In other words, both monkeys appeared to be experiencing and responding to internally generated visual imagery projected into the outer world. A specific example involved the complex threat behavior executed by monkeys when human observers approached too near the cages, consisting essentially of teeth baring and sudden jumps at the intruder. When the PCPA effect developed, this behavior was often emitted (videotape) when no one was in the vicinity (Dement et al., 1970, p. 352).

Monkeys treated with PCPA have displayed numerous other behaviors that have been cited as evidence of apparent perceptual distortions, if not hallucinations themselves. In one study reviewed by Boelkins (1973), a monkey was observed to make an oriented and focused visual search of his environment without apparent stimulus targets. In addition, there was an increase in a stereotyped vocalization pattern that functions as an alerting and warning bark "with no external stimulation visible or audible to the observer." Evidence of such perceptual disturbances induced by PCPA has also been offered by Whalen and Luttge (1970), who found that PCPA treatment in rats facilitates homosexual mountings but not heterosexual interactions. They argue that the drug works "not by enhancing sexual motivation, but rather by altering the male's ability to adequately distinguish appropriate sexual partners" (p. 1001).

Scheckel et al. (1968) found that the general behavioral changes in squirrel monkeys given THC were more relevant to the question of hallucinations than changes in operant responding. Low doses of THC (4 or 8 mg/kg) caused the monkey to sit quietly near the operant levers and look down at the lower part of the chamber. Higher doses seemed to induce apparent hallucinations that



... excited the monkeys and caused them to walk about the box, apparently looking at something the experimenters did not see, or crouch and move their heads from side to side and up and down as if watching some moving object. Some animals had a blank expression and gazed into space. We assumed that the animals had visual hallucinations. . . . In all monkeys given 32 or 64 mg/kg, this apparent hallucinatory reaction was more obvious. Monkeys moved quickly about the box, looked above and behind themselves, seemed to be in a state of panic, and appeared to fight with imaginary objects; their arms would swing rapidly through the air and they would attempt to grasp objects that were not there (Scheckel et al., 1968, p. 1467).

Similar behaviors have been reported with marihuana by McIsaac et al. (1971) and with inhalation of volatile solvents by Yanagita et al. (1970). Lagutina et al. (1964) observed that baboons injected with LSD (10–40  $\mu$ g/kg) exhibited orienting responses, hyperexcitability, and periodic catatonia. In addition, the animals grasped at objects in the air, jumped about the cage, and tried to escape “as if they had hallucinations.” Similar reactions were observed in a chimpanzee treated with LSD (800  $\mu$ g, p.o.) who struck at the air in front and above him, screamed, and displayed fear reactions without apparent stimuli:

He began to look at his right hand, which he extended about 8 in. before his eyes. Suddenly he screamed, beat the air before him with his right hand, and defecated. Then he lashed the air before his face with both hands, grimaced, leaped upwards, and screamed. He landed in a sitting position and covered his eyes with his hands. As he sat he continued to salivate and he began to whimper. He screamed once more and ran backward, beating at the air before him with both hands. He stopped, stared at the roof, and then looked quickly to his right. Once again he struck at the air over his head and screamed. Then he began to run about the floor, alternately screaming and whimpering . . . (Baldwin et al., 1957, pp. 46–47).

Interestingly, Baldwin and his co-workers compared this drug-induced behavior with that induced in chimpanzees by sensory isolation, concluding that both treatments produce identical behavioral syndromes. In another study, Evarts (1958) found that LSD (1 mg/kg) failed to impair the accuracy of monkeys' performance on a variety of learned responses but did produce a syndrome characterized by ataxia and loss of responsiveness to normal visual stimuli. Similar syndromes have been produced in monkeys exposed to conflict situations (Masserman, 1959). At feeding time, Masserman presented monkeys with a toy rubber snake in the food box or with unavoidable electric shock. These conflict procedures produced “experimental neuroses” coupled with hallucinatory behaviors:

Some monkeys also showed deep anachronistic regressions, extreme or bizarre affectivity and evidence of hallucinatory and delusional behavior such as unremitting searching and exploration or the recurrent seeking, chewing and swallowing of imaginary food while refusing real food immediately available (p. 100).

During cocaine self-administration studies in rhesus monkeys, Deneau et al. (1969) constantly observed “behavior consistent with visual hallucinations (staring and grasping at the wall) and tactile hallucinations (continued scratching and biting of the extremities, to the point of producing extensive wounds and even amputation of the digits)” (p. 41). Of course, the tactile hallucinatory behavior may have been the result of local irritation; but the description closely resembles



the human reports of "cocaine bugs." The latter, perhaps the most common hallucinations in cocaine users, consist of sensations of live insects or animals crawling on or under the skin. In man and monkey, such tactile sensations can lead to skin abrasions, chronic sores, and even local wounds (Woods and Downs, 1973).

Recently an attempt was made to develop an objective behavioral profile that could be used to distinguish the effects of hallucinogens from those of other drugs (Siegel et al., 1974). Saline, bromo-lysergic acid diethylamide (BOL), LSD, dimethyltryptamine, chlorpromazine, and *d*-amphetamine were administered to solitary adolescent rhesus monkeys whose behavior was observed, videotaped, and scored by blind observers in a number of categories. Hallucinogens could be distinguished from the other drugs by the increased frequency of unusual behaviors such as spasms, stereotypy, and inappropriate behavior. Hallucinogens also produced qualitative changes in behavior such as convulsive body jerks, grooming with hand covering face, walking around the cage with eyes closed, and ataxic locomotion. These investigators did not find significant hallucinogen-induced increases in behaviors (e.g., fear grimace, threat, tracking), which normally occur only in the presence of an appropriate stimulus; thus, they could not support the notion of "hallucinatory stimuli." Nonetheless, they did suggest that an hallucinogen-induced decrease in exploration time was due to a shift in attention toward internally generated stimuli.

Borenstein et al. (1969) found that LSD (100 $\mu$ g/kg) produced stereotypic behavior in *Macaca nemestria* monkeys. Such stereotypy was marked by reduced motor activity and incessant eyeball and head movements. The monkeys engaged in continuous exploration of their environments, and the authors identified this as "visual hallucinatory behavior." However, this conclusion would have been strengthened if the authors had tried to correlate the eye movement patterns with stimuli that may or may not have been fixated. Indeed, Cohen (1968) has stressed the need for this type of measure to identify the nature of hallucinatory behavior in monkeys, but to date no one has done so. However, several investigators have found that hallucinogens induce measurable changes in monkey brain activity which are correlated with changes in visual perception (e.g., Vuillon-Cacciuttolo and Balzamo, 1971). For example, Bermond and Bert (1969) reported that psilocybin (3 mg) enhanced the alertness of monkeys as estimated from EEG recordings, decreased spontaneous mobility, and increased the frequency of eye movements. The authors conclude that such behavioral patterns could be explained by alteration of visual perception (i.e., hallucinations). Recently Heath (1973) found that marihuana produces in the septal area of rhesus monkey brain an activation that could be associated with this observed heightened awareness as well as accompanying changes in emotional expressions.

#### LABORATORY STUDIES OF HALLUCINOGEN-INDUCED CHANGES IN PERCEPTION

The field and laboratory observations discussed previously emphasize the importance of considering the uniqueness of animal perception. The behavior of organisms is often guided by perceptions, and we can never really *know* the



perceptions of other animals, including those of our own species. Von Uexküll (1921) used the word *umwelt* to emphasize that each species perceives the world uniquely, and this constitutes a further limitation to the understanding of what is perceived by others. Nonetheless, some examples of animal behavior do agree with an intuitive sense of what is reasonable to infer, as in the mescaline-treated cat's fondling of a mouse or the THC-treated monkey's orientation to imaginary stimuli. Other examples are less apparent and must make us cautious about a priori assumptions about what an animal does and does not perceive in a given situation.

The question of whether an hallucinogen-treated animal perceives an hallucination can be approached in several ways. Bridger (1973) suggested two such approaches:

First is that in some way LSD and mescaline activate previously stored memory images independent of any external stimulus, and the animals show searching behavior, aggressive behavior, etc., without responding to a known external stimulus. The second approach assumes that an external signaling stimulus is necessary and that the animals have a decreased ability to differentiate this signaling from what is being signaled (p. 136).

Evidence supporting Bridger's first approach has already been discussed in terms of observations in the field and laboratory. Additional evidence might be found in studies that train animals to report perceptual events and then substitute hallucinogen treatment for the stimulus events themselves. Examples of such studies conducted with pigeons are discussed below. Bridger's second approach involves experiments in which we examine the effects of hallucinogens on externally signaled avoidance behavior in rats, and examples of these are also given below.

**Pigeons.** A number of studies on the perceptual effects of hallucinogens have been carried out in the pigeon because of that animal's visual acuity and proved ability to perform complex tasks. Typically, low doses of LSD (20–300  $\mu$ g/kg) improve the accuracy of some visual discriminations. For example, LSD causes an improvement in the accuracy of a brightness (Blough, 1957) and flicker discrimination (Becker et al., 1967), and little change in hue discrimination (Berryman et al., 1962). Higher doses usually lower the response rate, thus making it difficult to assess performance.

In the usual design of the experiments, pigeons are trained to respond (key peck) in the presence of one stimulus (S+) to gain access to a food reward (reinforcement), but responding in the presence of another stimulus (S–) is not reinforced. The two stimuli are presented on different trials, randomly alternated, and separated by blackout periods (intertrial intervals) during which stimuli are not presented and responses have no consequences. As the animal learns to discriminate between the two stimuli, responses in the presence of the nonreinforced stimulus and during the blackout period gradually disappear; that is, the animal learns that these do not earn rewards. However, in many studies with hallucinogens, the animals occasionally make inappropriate responses during the intertrial intervals. Since stimuli are not presented to the animal during these intervals, responses during that time are as inappropriate as responses on nonreinforced trials, and stimulus control is said to be disrupted. These responses



are of great interest because they are, in effect, false reports (i.e., animals are responding as if stimuli were present).

Siegel (1969) attempted to investigate hallucinogen-induced "false reports" in pigeons. In one initial experiment, not previously reported, 12 pigeons were placed in a totally dark operant discrimination unit and trained to peck at a rear-illuminated response key for food reinforcement. The animals were then divided into three groups of four birds each. Group 1 was trained to peck at the response key whenever a rear-projected slide was shown on the key. The slides, which constantly varied from trial to trial, consisted of a wide variety of geometric forms, colors, complex objects, and scenes of landscapes, houses, cars, and people. Most of the slides were obtained from commercial "psychedelic" light-show companies and were representative of the types of visual imagery reported with hallucinogenic reactions in man. Many of the slides displayed scenes in distorted and exaggerated form, and most contained examples of hallucinogen-induced geometric form-constants (cf. Klüver, 1966; Horowitz, this volume). The rationale for this choice in stimulus material was independently suggested by research psychiatrist Frank Ervin:

The animal could be conditioned to the type of geometrical patterns commonly seen in these hallucinosis. Then one could see if the animal responded more with LSD than did a control. This would be getting closer to an animal model of hallucination (in Smythies, 1970, p. 85).

Subjects received 20 daily sessions of discrimination training, and each session consisted of 40 successively presented slides, 20 blank (white light) slides (S-) and 20 with the features previously described (S+). All slides presented during a session differed from one another, and different sets of slides were presented at each session. Thus animals in Group 1 could earn reinforcements for responses to a variety of stimuli but were not rewarded for responses made when these stimuli were absent and only white light was present. In effect, the animals were trained to respond to the "concept" of "slide on" or "stimulus present," and these responses could be considered equivalent to the verbal statement "is" (i.e., when slide is on, or when stimuli are present, reinforcement is available). Conversely, animals in Group 2 were trained on the opposite problem: responses to "slide off" or white light only were rewarded (S+), and responses to "slide on" were not rewarded (S-). In other words, contingencies in Group 2 were equivalent to the verbal statement "is not" (i.e., the animal must learn that when stimulus is not present, or is absent, reinforcement is available). Animals in Group 3 received differential training on the problem white light on (S+), white light off (S-). After 20 training sessions, animals in Groups 1 and 2 were emitting 80 to 90% of their responses during S+ trials. Subjects were then given a series of drug sessions in which they were treated with a variety of doses of LSD, pentobarbital, or saline. At high doses of LSD (300-500  $\mu$ g/kg, i. p.) pigeons in Group 1 made significantly more responses to blank trials when compared with predrug or saline sessions; pigeons in Group 2 maintained their discrimination ratios but did not respond to as many "slide off" (S+) trials as they did during predrug and saline sessions.

Although it could be argued that LSD treatment merely broke down stimulus control for Group 1, resulting in lower discrimination ratios, such an explanation does not account for the unimpaired performance of Group 2. Indeed, pentobar-



bital (2–10 mg/kg), which does break down stimulus control in some visual discrimination tasks for pigeons, only suppressed responding here: there were no concomitant changes in discrimination accuracy. Since animals in Group 3 showed no disruption of the simple white light on-off problem under the same doses of LSD, this stimulus control notion cannot be supported. Another explanation is that pigeons in Groups 1 and 2 were reporting perceptual events. Accordingly, the responses of pigeons in Group 1 to blank trials in LSD sessions may be interpreted as statements that stimuli were perceived to be present at these times. Similarly, the maintenance of discrimination ratios for Groups 2 and 3 in LSD sessions indicates that stimuli could still be accurately perceived and discriminated. Furthermore, the failure of pigeons in Group 2 to respond to some of the “slide off” trials in LSD sessions suggests that these animals may have been perceiving stimuli at these times. Since these effects were not observed in saline or pentobarbital sessions, it is possible that such results are a consequence of the LSD treatment, if not hallucinatory stimuli per se.

Another way of conceptualizing the verbal statements “is” and “is not” involves the discriminations of matching and oddity. When an animal matches stimuli, he chooses a response that in essence says what the stimulus “is.” On the other hand, oddity or “nonmatching” involves choosing what the stimulus “is not.” Several investigators have observed that matching and oddity performances in the pigeon are differentially affected by pentobarbital (Cumming and Berryman, 1965; Nevin and Liebold, 1966). Oddity performance is far less sensitive to this drug than matching performance, which is readily disrupted by low doses. Utilizing the more sensitive matching procedure, Siegel (1969) studied the effects of hallucinogens on the separate dimensions of form and color, dimensions along which humans report hallucinogenic disturbances (Hoffer and Osmond, 1967, pp. 111ff).

In the Siegel study, four pigeons were trained in an operant unit equipped with three response keys. During a 10-second intertrial interval, all response keys were dark. A trial started when the two side keys were illuminated with white light and the center key was illuminated with one of three groups of stimuli. The stimulus on the center key was either a white triangle (the standard) or another form or a color. The forms included squares, circles, rectangles, lines, dots, and crosses (Fig. 3). Colors included various changes in hue, saturation, or brightness. If the standard triangle appeared, the animal was required to respond to the center key to earn food reinforcement. If a color appeared, responses to the right key were reinforced, whereas if a form other than triangle appeared, responses to the left key were rewarded. The stimuli were constantly varied from trial to trial, and the animals, in effect, had to learn the concepts of “form change” and “color change” to select correctly when presented with a novel stimulus configuration.

After the animals had mastered this rather difficult discrimination, they were given a series of drug sessions. In general, most drug treatments did not disrupt accuracy of this performance. When given several doses of a *Cannabis* extract or LSD, pigeons suppressed responding for some minutes, but when they resumed, their performance remained relatively unchanged. Only the high dose of LSD (750  $\mu$ g/kg) significantly disrupted accuracy. Nonetheless, a very interesting effect emerged when the type of errors the animals did make (they usually performed between 80 and 90% accuracy on this problem) were analyzed. Table 1 shows the



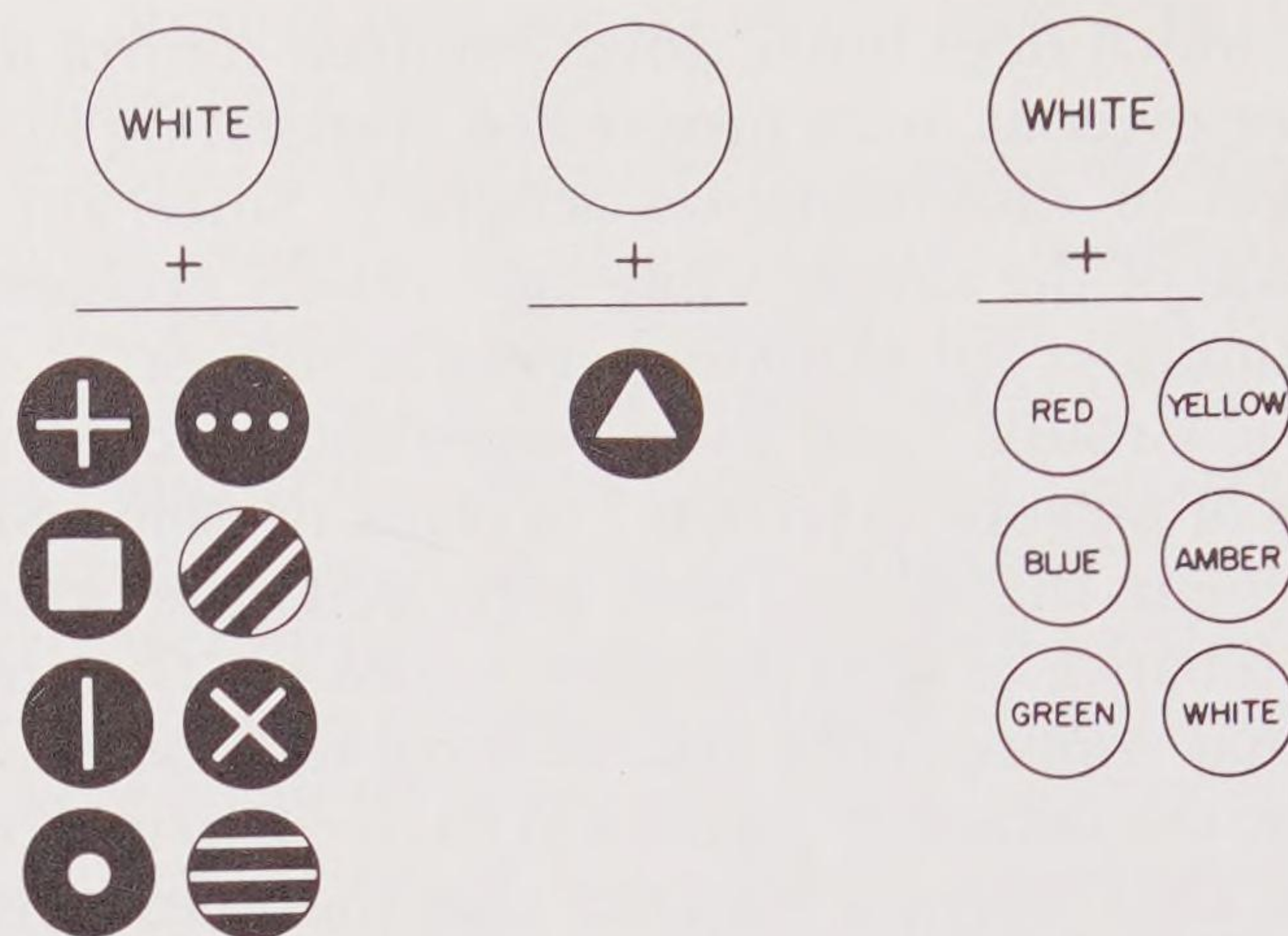


**Figure 3** Response keys and sample stimuli used in pigeon discrimination study (Siegel, 1969). The two side keys were always illuminated with white light. Other stimuli were displayed on the center key. When a triangle was displayed, responses to the center key were reinforced (+). When other forms were displayed, responses to the left (white) key were reinforced (+). When colors were displayed, responses to the right (white) key were reinforced (+).

mean distribution of errors during all drug sessions. Errors were scored according to the following procedure. Responses to the color key when either a form or standard triangle was displayed were scored as color errors. Responses to the center key when either a form or color was displayed were scored as standard (triangle) errors. Similarly, responses to the form key when either a color or the standard was displayed were scored as form errors. As Table 1 indicates, during the pretest mean of 10 sessions, errors were relatively equally distributed between form and color keys. However, with  $300\mu\text{g/kg}$  of LSD there was a significant increase in the number of color errors. This increase was also seen with the two other doses of LSD as well as with the *Cannabis* treatments. Equal doses of BOL, which is similar to LSD except for the psychological effects and EEG activation, produced no changes in error distribution.

Several interpretations of these findings suggest themselves. First, it may be argued that the hallucinogens used simply break down stimulus control. This notion may explain the decrement in performance under high doses of LSD, but it fails to account for the accuracy of performance under comparable doses of *Cannabis*. Indeed, a breakdown in stimulus control might also be expected to distribute errors more equally among the three keys. In addition, pentobarbital did produce some decrement in accuracy of the discrimination with no concomitant change in error distribution; thus the stimulus control interpretation must be regarded with caution. Alternatively, Siegel argues that "a particularly attractive but more speculative explanation is that animals were reporting perceptual events" (p. 8). Pigeons under LSD and *Cannabis* may have been reporting color changes when no color changes were occurring on the center key. Since color errors did not prevail under BOL, the results seem to be at least a consequence of the central nervous system effects of the drugs, if not the hallucinogenic properties themselves.



TABLE 1. MEAN PERCENT DISTRIBUTION OF PIGEON ERRORS DURING ALL DRUG SESSIONS<sup>a</sup> (N = 4)

| Errors   | Pretest | Saline | LSD       |           |           |           | BOL       |          | Cannabis |          | Pento- |  |
|----------|---------|--------|-----------|-----------|-----------|-----------|-----------|----------|----------|----------|--------|--|
|          |         |        | 300 µg/kg | 500 µg/kg | 750 µg/kg | 500 µg/kg | 750 µg/kg | 20 mg/kg | 30 mg/kg | 10 mg/kg |        |  |
| Form     | 53.3    | 52.5   | 33.3      | 7.1       | 11.9      | 63.2      | 55.8      | 8.7      | 3.3      | 60.6     |        |  |
| Standard | 2.4     | 6.4    | 3.7       | 5.2       | 4.8       | 1.1       | 2.3       | 5.0      | 2.1      | 3.2      |        |  |
| Color    | 44.3    | 41.1   | 63.0      | 87.7      | 83.3      | 35.7      | 42.9      | 86.3     | 94.6     | 36.2     |        |  |

<sup>a</sup>Adapted from Siegel (1969).



Using a similar procedure with monkeys, Ferraro (1972) found that THC (1 mg/kg, p.o.) produced a significant decrease in correct responses to a delayed matching-to-sample problem. In this procedure, a time delay is introduced between the sample stimulus and the choice stimuli to which the animal will try to match the sample. As the delay grows longer, the problem becomes more difficult for the animal. THC produced no decrement at 0-second delay, thus demonstrating that the animal still had the motivation, attention, and motor responses necessary for correct responding. The same dose of THC, however, disrupted performance at delays of 5, 10, and 20 seconds, indicating some type of interaction between perception and short-term memory.

**Rats.** Several studies with rats have demonstrated that hallucinogens selectively impair externally signaled behaviors. In the simple version of one of these procedures, the conditioned avoidance response, an animal is placed on an electric grid adjacent to a safe (nonshocked) area. A tone or light is presented to the animal, followed a few seconds later by a shock delivered to the grid. The animal soon learns to take the appropriate avoiding action and moves to the safe area as soon as the light or tone is presented. When treated with intermediate doses of LSD, psilocybin, dimethyltryptamine, or other hallucinogenic amphetamines, the reaction time is at first increased and then decreased (Smythies and Sykes, 1964). In other words, the animal takes longer to respond to the signal and avoid the shock. Only the hallucinogens seem to have this characteristic "biphasic" response, and so far it has not been induced by any other compound (Smythies et al., 1969).

That hallucinogens selectively impair an animal's discrimination of external signals is further illustrated by studies involving a free operant avoidance procedure (Bovet and Gatti, 1963; Beaton et al., 1969; Smythies et al., 1969; Webster et al., 1971). In this procedure, also referred to as Sidman avoidance, the animal can keep on postponing the shock by pressing a lever that continually resets a shock delivery circuit for a fixed time period. The onset of shock is preceded by a 10-second light, after which animals usually learn to press the lever and postpone the shock. In this way, the animal can avoid shock as long as he responds efficiently. Hallucinogens characteristically increase the proportion of inefficient responses—premature (made before the light comes on) and late (made too late to avoid shock)—and decreases the proportion of efficient responses. The reaction time (the time between onset of the light or the conditioned stimulus and the rat's response) shows a decrease with low doses and an increase with high doses.

### OVERVIEW: DO ANIMALS HALLUCINATE?

The traditional assumption that *Homo sapiens* is the only species that uses hallucinogens is challenged by field observations on several other species that either by accident or design also self-administer these drugs. Many of the examples cited here need further controlled psychopharmacological study to identify the biological, pharmacological, and environmental variables. Nonetheless, it is clear that such self-administrations dramatically affect the animals' behavior.

The extent to which such behaviors support the notion of animals having hallucinations depends on what we are willing to infer about the behavior. Such



inferences can be dangerously speculative in natural milieus, where pharmacological and behavioral controls are lacking. However, in more controlled laboratory studies there are abundant observations of hallucinogen-induced perceptual changes, if not hallucinations themselves. Mice treated with such drugs as LSD exhibit bizarre postures, aggression, fear, paroxysmal ear scratching, head twitching, and other behaviors. The descriptions of the mice's locomotion and exploration have included numerous reports of reactions to stimuli that were not present. This has prompted many investigators to speak of apparent hallucinatory behavior. At the very least, such drug-induced behaviors occur at doses correlated with human hallucinogenic doses. Cats treated with hallucinogens manifest similar bizarre postures, head shaking, and inappropriate approach and withdrawal behavior, as well as orienting responses to stimuli that are not present in the experimental situation. Monkeys treated with hallucinogens execute oriented and focused visual searching of their environments without apparent stimulus targets, exhibit oral syndromes described as somatosensory hallucinations, and frequently appear to fight with "imaginary" objects.

Taken together, these studies indicate that so-called drug-induced hallucinations appear clearer and more purposeful as observations are made higher up the phylogenetic scale. The comparatively limited behavioral repertoires of rodents and cats, and their basic "alien" nature, prevent human observers from agreeing on the interpretation of drug-induced changes. However, with infrahuman primates the range of behaviors is fuller and more familiar, the temptation to anthropomorphize is greater, and human observers find the reactions to hallucinogens more convincingly hallucinatory. If such observations were extended to hallucinogen-induced changes in *Homo sapiens*, it is doubtful whether any clearer examples of hallucinatory behavior could be found than those provided earlier. For in all organisms, this behavior is probably related to hallucinogen-induced states of central nervous system excitation and sympathetic nervous system arousal, marked by a behavioral "turning inward toward a mental dimension at the expense of the physical" (Fischer, 1971a, p. 897). Consequently, it is not surprising to find that the initial behavioral excitation and arousal induced by hallucinogens is often followed by quiescence and catatonia. Elsewhere, it has been shown that this contributes to the tendency of hallucinogen-treated animals to avoid further stimulation, thus to isolate themselves from social groups (Siegel, 1973a).

It is probably fortunate for the study of hallucinations that animals do not primarily react to hallucinogens with understandable verbal responses or "higher level cognitions," since that much more of their behavior is "outside" the organism and observable to others. Such behaviors are strikingly similar to those of preverbal children given the hallucinogenic anesthetic ketamine prior to surgical procedures (Siegel et al., 1971). The recovery behavior of these children is frequently marked by pointing, reaching, and grasping at the air; spontaneous head and eye orientations in the absence of apparent stimuli; and, in one case, a crawling away from an area of the bed which the child continued to strike at with his hands, screaming and crying.

Many of these studies have included the observation that hallucinogens increase stereotyped behavior (e.g., oral syndrome, grooming, head twitching). Stereotyped behavior is usually defined as "that which has little variation and



might include a single activity performed continuously or a repertory of a few sequences which dominate behavior" (Ellinwood and Sudilovsky, 1973, p. 52). In most instances these stereotypies appear "nondistractable" and "driven" or performed in a rapid and repetitious manner, and they seem to evolve from motor components of investigatory and exploratory behaviors. Examples of hallucinogen-induced stereotyped behavior, which include increased head twitching, paroxysmal ear scratching, and grooming, have been observed in rats, rabbits, cats, monkeys, and man (Knoll et al., 1971; Randrup and Munkvad, 1971; Rylander, 1971). There even appear to be similarities between animals and man in operant behaviors under some of these drugs, such as amphetamines (Weiss and Laties, 1971).

Recently Ellinwood and Sudilovsky (1973) compared amphetamine-induced stereotypy across species and developed a model of how hallucinatory behavior might be generated from such a basis. These authors note that as one looks along the phylogenetic scale from rodents to primates, there appear more developed patterns of amphetamine-induced stereotypy: rats sniff, nose, and lick; cats orient and track; and primates use coordinated hand-eye movements directed toward external objects or their own bodies. Often distinctive body postures and activities accompany the development of such behavior. For example, in the cat such postures were characterized by hyperreactivity:

In the end stages of the chronic intoxication cycle, even though the animal might be in a frozen posture, sudden orienting movements toward a real or "hallucinated" stimulus were often observed. Many animals appeared to be increasingly aware of minor stimuli in their environment and acutely apprehensive about it . . . Not infrequently a cat would jump back and turn vigorously to one side in response to a nonexistent [apparently hallucinatory] stimulus (Ellinwood et al., 1973, pp. 1089-1090).

These findings can be compared with amphetamine-induced behaviors in primates, which include incessant examining, rubbing, and picking of the skin. Interestingly, both human and infrahuman primates use the forefinger probe and pincer grasp in executing these behaviors. Hallucinations may easily develop from such behaviors in man:

. . . many of the patients with "grooming responses" developed marked delusions of parasitosis and spent many hours examining their skin and digging out imagined encysted parasites. These delusions appeared to develop out of earlier sequences of skin sensations and repetitive "grooming responses" that evolved over time. . . . Other repetitious examining, searching, and sorting behaviors are directed towards the external environment and are often associated with an intense feeling of curiosity. . . . Amphetamine addicts frequently state that the scanning, prying, and probing behaviors subsequently evolve into what is at first a pleasurable sense of suspiciousness in the old meaning of suspiciousness: that is, looking beneath the surface for the truth or meaning (literally, to look from below). They describe looking for meaningful details and for relationships between details, or they often impart great meaning to trivial details. . . . Progressing from this stage, the previous suspiciousness flourished to a more paranoid form, and still later the patient was often fearful and not infrequently panic-stricken, agitated, and overreactive. At this point it is not unusual for patients to suddenly misinterpret stimuli and often have delusions and hallucinations (Ellinwood and Sudilovsky, 1973, pp. 52-53).



Can such hallucinations develop in animals? Let us examine this question in terms of the stages of the model proposed. First, there is the observed increase in stereotyped behaviors, and this stage is observed in both animals and man. Second, there is a "looking for meaningful details" or attributing great meaning to trivial details. The second stage can also be conceptualized in terms of attentional shifts. If an animal shifts his attention from relevant cues to irrelevant cues (e.g., inner sensations, "imagined stimuli"), we might predict an impairment in the performance of discriminations that require the animal to attend exclusively to relevant cues. Indeed, there appears to be substantial evidence that hallucinogens disrupt animal discrimination performance in specific ways consistent with this notion. For example, Sharpe et al. (1967) found that in squirrel monkeys simple discriminations were unaffected, and only fine or difficult size discriminations were impaired by LSD treatment (10–40  $\mu\text{g/kg}$ ). It is well known that in making difficult discriminations animals often shift their attention from the relevant dimensions to irrelevant stimuli. Thus the authors speculated that LSD may have facilitated such attentional shifts to irrelevant stimuli.

The third stage of the amphetamine model involves a state of fear, panic, and overreaction, sometimes manifested in the misinterpretation of stimuli. It is clear from the observational studies discussed that hallucinogen-treated animals display fear, panic, and hyperreactivity. The increase in aggressive postures, the severe autonomic reactions, and the tracking and grasping of imaginary objects all seem to argue in favor of Stage 3 in animals. Another example of Stage 3 fear and autonomic reactions was found in chimpanzees administered LSD (30  $\mu\text{g/kg}$ ):

Suddenly, Sampson, the normal animal, stopped his play. His pupils dilated. He seemed to stare, and his mouth opened in a grimace as he began to salivate. His face flattened, and he began to hyperventilate. Then his hair stood on end, and he screamed and leaped backward. As he moved, he struck at the air before him with both hands (Baldwin et al., 1959, p. 473).

Furthermore, the hallucinogen-induced impairment of externally signaled avoidance behavior seems to support the notion that these animals were also misinterpreting stimuli. There is also some evidence that the fear in Stage 3 is an important determinant in both human and infrahuman reactions to hallucinogens. For example, human reaction to hallucinogens are often dependent on the degree of fear or anxiety present. Similarly, the effect of mescaline on rat behavior has been shown to be greatly potentiated when the rat is placed in a fear-producing situation where unavoidable shock is signaled (Smythies et al., 1969).

Thus far we have seen that the ingredients for the three stages of our developmental model of hallucinations are probably present for hallucinogen-treated animals. However, Ellinwood and Sudilovsky mention that delusions often accompany such hallucinations; and other writers have even stated this as a necessary condition for true hallucinations. In other words, true hallucinations involve the perception of stimuli that are not really there, concomitant with a delusion that they are indeed present (James, 1890). It could be argued that we have no way of knowing about an animal's delusions or false beliefs and, therefore, we can never know whether an animal is truly hallucinating. But animals might confirm the presence of hallucinations by responding to them, trying to grasp them, tracking



them, avoiding them, or in some other way behaving as if "things" were actually there. The sheer abundance of the observational studies reporting such phenomena cannot be lightly dismissed. That animals are also capable of manifesting false beliefs in the perception of stimuli has been demonstrated in rat studies on the conditioned avoidance response. Here, in a sense, the animal acquires a true belief in the external signal and learns to avoid the incipient shock. The animal's avoidance behavior is true because it is conformable to a standard pattern. It is a belief because the animal's avoidance response is a deliberate habitual readiness to act in a certain manner under appropriate conditions. The hallucinogen-treated rat waits too long to avoid quickly and sometimes endures shock. His behavior is now indicative of a false belief: it is no longer conformable to a standard rule established by training. Similarly, the persistent errors made in the Sidman avoidance procedures (premature and late responses) have no basis in the physical reality of the situation, but the animal behaves as if the trust, confidence, or reliance placed in the external signal by training is no longer present. Simply stated, the animal behaves in accordance with the description that he is deluded. With all this in mind, we return to our initial question: can animals hallucinate? Yes, they can. Do animals hallucinate? Yes, they do. We all do.

## PART II: MAN

True perceptions involve objects that are really there or really not there. Psychologist William James characterized such perceptions by the presence of "objective reality." Conversely, James defined an hallucination as having no objective stimulus at all:

They are often talked of as mental images projected outwards by mistake. But where an hallucination is complete, it is more than a mental image. An hallucination is a strictly sensational form of consciousness, as good and true as if there were a real object there. The object happens not to be there, that is all (James, 1890, p. 115).

True hallucinations are distinguished from pseudohallucinations, which lack the character of "objective reality." Both types, however, share the qualities of being vivid, minute, detailed, abrupt, and spontaneous. James described the hallucinations of opium, hashish, and belladonna as a mixture of pseudohallucination, true hallucination, and illusion. He cites the following account from a friend who ingested hashish:

Directly I lay down upon a sofa there appeared before my eyes several rows of human hands, which oscillated for a moment, revolved and then changed to spoons. The same motions were repeated, the objects changing to wheels, tin soldiers, lamp-posts, brooms, and countless other absurdities. . . . I saw at least a thousand different objects. These whirling images did not appear like the realities of life, but had the character of the secondary images seen in the eye after looking at some brightly-illuminated object. . . . I became aware of the fact that my pulse was beating rapidly. . . . I could feel each pulsation through my whole system. . . . There were moments of apparent lucidity, when it seemed as if I could see within myself, and watch the pumping of my heart. A strange fear came over me, a certainty that I should never recover from the effects. . . . Suddenly there was a roar and a blast of sound and the word "Ismaral". . . . I thought of a fox, and instantly I was



transformed into that animal. I could distinctly feel myself a fox, could see my long ears and bushy tail, and by a sort of introversion felt that my complete anatomy was that of a fox. Suddenly, the point of vision changed. My eyes seemed to be located at the back of my mouth; I looked out between the parted lips, saw the two rows of pointed teeth, and, closing my mouth with a snap, saw—nothing . . . the whirling images appeared again. . . . It was an image of a double-faced doll, with a cylindrical body, running down to a point like a peg-top. It was always the same, having a sort of crown on its head, and painted in two colors, green and brown, on a background of blue (pp. 121–122).

It is clear from this account that the hashish experience generated visual, auditory, kinesthetic, as well as emotional reports. Despite the alleged distinctiveness of the experiences, it is doubtful whether the subject was ever convinced of the reality of his perceptions. Although James calls these events hallucinations, a true hallucination, one that “fools” the subject and appears “out there,” is rare in drug-induced states. Such reports as the letter just quoted are more properly classified as pseudohallucinations, since the perceptions appear to lack the concomitant delusion that they really exist. Other researchers have labeled such phenomena as “reported visual sensations,” “fantasies,” “visions,” “imagination,” “inner events,” “private events,” and “conditioned sensations.” Still others speak of the “imagery of hallucinations” by broadly defining hallucination to include any spontaneous imagery that might be taken for a perception, even if the subject knows that he is not perceiving (Hebb, 1968). It is in this latter sense that we speak of the visual imagery of drug-induced hallucinations in the following sections.

A number of studies have attempted to distinguish between normal mental imagery and the imagery of hallucinations. Most view mental imagery as “all those quasi-sensory or quasi-perceptual experiences of which we are self-consciously aware, and which exist for us in the absence of those stimulus conditions that are known to produce their genuine sensory or perceptual counterparts” (Richardson, 1969, pp. 2–3). Accordingly, hallucinations are referred to as exaggerated mental images (Roman and Landis, 1945; Pylsyshyn, 1973) or cognitive constructions elaborated on by expectancies and past experiences (Segal, 1971). Furthermore, hallucinations are considered to be more vivid and more real than normal mental images (Stockings, 1940; Seitz and Molholm, 1947; Aggernaes, 1972a, 1972b; Mintz and Alpert, 1972). When the imagery of hallucinations is drug-induced, it is readily distinguished from other forms of imagery in that the former has its own space in which the objects appear and the action unfolds (Masters and Houston, 1967). Some of our subjects who reported such imagery with eyes open have coined the phrase “intraspatials” to indicate that the space or locus of these events is interposed with real physical stimuli and does not interfere with them.

Analysis of the imagery of such drug-induced hallucinations is intimately dependent on the words and pictures used in their description. James’s friend who ingested hashish tells us that literally a thousand things were seen; but he describes very few of them. Therefore it is not surprising that more than a few scientific investigators have suggested that the talent of a poet like Milton is needed to fully describe hashish-induced hallucinations (Robinson, 1930).

But poets and scientists have long argued over their respective abilities to describe and interpret such complex phenomena. The argument is best illustrated by the classic rivalry between Purkinje and Goethe, who visited and corresponded with each other in the early nineteenth century (cf. Kruta, 1968; Ratliff, 1971). Purkinje’s scientific method was *heautognosis*, in which one observes and



experiments on one's own body. Combining this method with an ethic of laborious research and analysis, Purkinje investigated the behavioral and hallucinogenic effects of digitalis, nutmeg, and opium. He treated the visual imagery and allied phenomena as something that could be accurately represented and could have an informative scientific relationship with the actual processes involved in their production. Purkinje's pioneering work with heautognosis in the study of entoptic phenomena and vertigo is testimony to the success of this method. Goethe disagreed with this approach and expressed his own ethic as a poet: "... the knowledge of the world is inborn in a true poet, that in no way does he need much experience or great empiricism for its depiction" (in Kruta, 1968, p. 24).

Goethe's inquiry into plant morphology (*Zur Morphologie und Naturwissenschaft*) presented numerous images of the form and structure of plant development. However, whereas Purkinje used the image as a *representation* that could only abstract from phenomena those aspects which conform to accepted systems of scientific explanation, Goethe used the image as an *illustration* that had to be elaborately abstracted from reality to convey the essential beauty of nature. His visual image of the ideal plant was beautiful and moving but lacked a scientifically meaningful relationship to the processes of plant growth it was intended to represent (Ritterbush, 1968). Nonetheless, the approach epitomized by Goethe has been as successful in depicting the experiential aspects of hallucinations as Purkinje's approach has been in conveying the sensory components. Therefore, it is not surprising that the literary world is replete with analyses of the imagery of hallucinations (cf. Abrams, 1970; Hayer, 1970) and that the scientific literature contains many artistic and literary excursions into drug-induced imagery. For example, numerous descriptions of drug-induced hallucinations can be found in poetry (e.g., Ginsberg, 1961; Leary, 1966a; Durr, 1970), essays (e.g., Huxley, 1959; Watts, 1962), novels (e.g., Larner, 1968), and art and film (Masters and Houston, 1968), as well as in other forms (e.g., Metzner, 1968; Wolfe, 1968). Indeed some poets have combined approaches as in Henri Michaux's (1963) drawings and essays on his mescaline experiences or Jean Cocteau's (1957) art and poetry of opium addiction. Similarly, in the sciences, researchers have often employed literary and artistic devices such as poetry (e.g., Leary, 1966a) and graphics (e.g., Szuman, 1930) to supplement their findings.

It is not the purpose of the present section to argue for or against the positions represented by Purkinje and Goethe. Both approaches are immensely valuable in communicating aspects of the imagery of drug-induced hallucinations. Indeed, as Polish scientist and artist Szuman wrote concerning the imagery of mescaline-induced hallucinations: "It is easy to describe the content of *what* was seen as trees, jewelry, the sea, etc., but it is difficult to describe *how* it is seen and this can only be expressed in a drawing" (translated from original: Szuman, 1930, p. 159). Accordingly, we have chosen to include graphic representations and illustrations of drug-induced imagery as found in both our experiments as well as those of others.

### HISTORICAL INTRODUCTION

In 1845 French psychiatrist Jacques Moreau published one of the first books on hashish, in which he developed the principle of "objective experimentation" (Purkinje's heautognosis) in the study of mental disorders such as hallucinations.



Moreau claimed that one should study mental illness by provoking it artificially through the ingestion of hashish, which possessed the characteristics of plunging one into an hallucinatory state while preserving the ability to observe and report events. Moreau described hallucinations as being similar to dreams wherein imagined visual, auditory, and tactile stimuli appear to be part of reality. He noted that the psychological phenomena of hallucinations were basically the same whether induced by nitrous oxide, opium, alcohol, thorny apple, belladonna, henbane, half-sleep or total sleep, dizziness, fevers, convulsive disorders, neuroses, hunger, thirst, or intense cold. With uncanny insight into what future neurophysiological research would reveal, Moreau believed that the hallucinatory state resulted from excitation of the brain which enabled imagined thoughts and memories to become transformed into the sensory impressions of visions and sounds:

... the hallucinating person hears his own thoughts as he sees, hears the creations of his imagination as he is moved by his memories ... and, what is even more extraordinary, certain combinations of thought are transformed into sensory impressions—that is to say, are endowed with the property of acting physically upon our senses in the manner of exterior stimuli (translated from original: Moreau, 1845, p. 168).

After experimenting on both himself and his patients, Moreau tried to persuade his colleagues at the Hôpital de Bicêtre to try hashish for themselves. His medical friends were hesitant to accept this idea of “objective experimentation,” but the Bohemian artists and writers of nineteenth century Paris were more receptive. Among them was novelist Théophile Gautier, who became interested in the visual imagery of hashish hallucinations. Gautier described some of his imagery after eating the marihuana resin:

Little by little the salon was filled with extraordinary figures ... as if I were the king of the feast, each figure came up in turn into the luminous circle of which I was the center. ... A bluish haze, an Elysian day, a reflection of an azurine grotto, formed, in the room, an atmosphere where I could see uncertain shapes vaguely tremble; ... After some moments of contemplation and by a strange miracle, I myself melted into the objects I regarded; I became that very object (in Ebin, 1961, pp. 9–13).

Gautier went on to organize the Club des Haschichins, which included Honoré de Balzac, Charles Baudelaire, Alexander Dumas, and Victor Hugo. The members' writings emphasized various aspects of their hashish experiences, including the intense and rapid flow of images. Throughout their reports one can find frequent references to colorful and vivid images, often composed of such forms as wheels, whirlpools, spirals, and rainbows (see Ebin, 1961). However, the drug experience so overwhelmed these early writers that a detailed analysis seemed almost impossible. As Baudelaire wrote in “The Poem of Hashish” (1857):

... in the more common effect the images are so multiplied and superimposed that all harmony is lost; the brain fails to keep pace with its impressions, still less to codify and control them (in Regardie, 1968, p. 108).

Although reluctant to follow Moreau's advice and use hashish, P. Max Simon (1888) studied the imagery of schizophrenic hallucinations in his patients at Asile. He reported the consistent occurrence of spider webs, ropes, meshes, and balls in



the visual imagery of his hallucinating patients. These images, like the images of hashish hallucinations, appeared suddenly and changed constantly from one form to another. Some years later, fellow countryman Dheur (1899) suggested that these visual images appeared to display consistent movement patterns as form changes occurred.

While these events were taking place in Europe, the American Fitzhugh Ludlow (1857) published a journalistic account of hashish experiences based on his self-experimentation. Ludlow was so impressed by the consistent and predictable nature of the visual imagery that he even attempted to formulate two "laws of hasheesh operation":

First, after the completion of any one fantasia has arrived, there almost invariably succeeds a shifting of the action to some other stage entirely different in its surroundings. In this transition the general character of the emotion may remain unchanged. . . . Second, after the full storm of a vision of intense sublimity has blown past the hasheesh eater, his next vision is generally of a quiet, relaxing, and recreating nature (pp. 36-37).

These "fantasias" were not unique to the hashish experience. Several other hallucinogens were reported to be equally capable of eliciting such imagery. Lewin (1924, 1931) noted that the smoking of marihuana frequently produced hallucinations such as "fireworks, rockets, and many-coloured stars." When mescaline was ingested and the subject closed his eyes or entered a dark room, forms and colors became even more vivid. The forms included "coloured arabesques," "carpets," "filigree lacework," "stars," "crystals," and "geometrical forms of all kinds." Lewin's account is remarkably similar to such other descriptions of mescaline-induced visual imagery as Beringer's (1927) report of colored arabesques, crystals, and crosses that appeared repeatedly during the latter investigator's experiences. Surprisingly similar imagery has been noted for alcohol delirium tremens (Clarke, 1878; Brinkmann, 1972), *Amanita muscaria* (Wasson and Wasson, 1957), antihistamines (Csillag and Landauer, 1973), various methoxy amphetamines (Shulgin, 1970), numerous anesthetics (Smith, 1972), *Banisteriopsis* (Harner, 1968; Dobkin de Rios, 1972), various forms of *Cannabis* (Kanner and Schilder, 1930; Bromberg, 1934; Lucena, 1950), carbon dioxide (Meduna, 1952), *Datura stramonium* (Boismont, 1853; Gowdy, 1972), harmala alkaloids (Naranjo, 1967), ketamine (Kreuscher, 1969; Collier, 1972), LSD (Bliss and Clarke, 1962; Masters and Houston, 1967), marihuana (Keeler, 1968; Keeler et al., 1971), mescaline (Zador, 1930), nitrous oxide (Davy, 1800; Müller, 1826; Steinberg, 1956; Sheldin and Wallace, 1972; Sheldin et al., 1973), peyote (Spindler, 1952; Masters and Houston, 1967), psilocybin mushrooms (Heim and Wasson, 1958), and tobacco (Lane, 1845; Shaw, 1849). In addition, visual imagery has been reported for a wide variety of classic hallucinogens including plant  $\beta$ -phenethylamines, ololiuqui, indole hallucinogens derived from tryptophan, cholinergic-blocking agents, and many other drugs (see reviews by Hoffer and Osmond, 1967; Jarvik, 1970). Also, undefined hallucinatory effects have been reported to be associated with alcoholic intoxication (Scott et al., 1969; Wolin, 1973; Wolin and Mello, 1973) and with chemotherapy involving amantadine, anticholinergic drugs, cortisol, cyclosersine, and digitalis (Shader, 1972; Harper and Knothe, 1973). However, it should be noted that the hallucinogenic effects of many drugs including some classified pharmacologically as hallucinogens (e.g.,



bufotenine) and some listed previously (e.g., tobacco) are still in dispute (cp. Fabing and Hawkins, 1956; Turner and Merlis, 1959; Janiger and Dobkin de Rios, 1973).

### THE EXPERIMENTAL ANALYSIS OF DRUG-INDUCED IMAGERY

Despite the frequent reports of drug-induced visual imagery, it was not until the work of Heinrich Klüver (1926, 1928, 1942, 1966) that the analysis of this phenomenon began. Klüver reported that following the ingestion of mescaline, visual imagery could be observed with either closed or opened eyes and that in the latter case, it was "impossible to look at walls without seeing them covered with visionary phenomena." The images generated in his own mescaline experiments, coupled with data reported by other investigators, were meticulously analyzed and the consistencies became apparent:

So far the analysis of the records published has yielded a number of forms and form elements which must be considered typical for mescal visions. No matter how strong the inter- and intra-individual differences may be, the records are remarkably uniform as to the appearance of the above-described forms and configurations. We may call them form-constants, implying that a certain number of them appear in almost all mescal visions and that many "atypical" visions are upon close examination nothing but variations of these form-constants (Klüver, 1966, p. 22).

These form-constants included four types. One type was always referred to by terms such as grating, lattice, fretwork, filigree, honeycomb, or chessboard design; the second resembled cobweb figures; the third was described by terms such as tunnel, funnel, alley, cone, or vessel; and spiral figures were designated as the fourth type. The form-constants were further characterized by varied and saturated colors, intense brightness, and symmetrical configuration. The visions seemed to be localized at reading distance, varied greatly in apparent size, and, generally, could not be consciously influenced by "thoughts" or "will." Stein (1928) confirmed the presence of these hallucinatory form-constants in mescaline intoxications. Szuman (1930) also found evidence of these constants in the mescaline state when the eyes were closed. When the subject opened his eyes, the patterns would appear projected against the real world as "pictures painted before your imagination." Szuman found that the images were often a repetition of the same motif, but displayed in different arrangements and filling the entire visual field.

Klüver made the critical observation that the same form-constants appeared in hypnagogic hallucinations (just prior to falling asleep), in insulin hypoglycemia, and, occasionally, in fever deliriums. McKellar (1957) reviewed studies suggesting that these "regularities" appear in many forms of human visualization including visions produced by mescaline, hypnagogic states, psychotic states, measles, malaria, tonsillitis, and influenza. Hypnagogic images were described by the Marquis d'Hervey in an 1867 monograph entitled *Les Rêves et les Moyens de les Diriger* as "wheels of light, tiny revolving suns, colored bubbles rising and falling . . . bright lines that cross and interlace, that roll up and make circles, lozenges, and other geometric shapes" (cited in MacKenzie, 1965, p. 108). Fever delirium hallucinations reported by Kandinsky (1881) bear a close resemblance to the mescaline imagery reported above by Szuman:



These vivid visual pictures completely covered real objects. During a week I saw on one and the same wall, covered with smooth uniformly colored wallpaper, a series of large pictures set in wonderfully gilded frames, landscapes, views of the seashore, sometimes portraits, in which the colors were just as vivid as in the real pictures of an Italian artist. . . . Hallucinations occurred as often with open eyes as with closed ones. In the first case they were projected on the surfaces of the floor, the ceiling, or the wall, or they appear in space, covering the objects that lie behind them. In one case the real environment disappeared completely and was suddenly replaced by an entirely new one; I suddenly saw myself transported out of the room to the shore of a bay . . . with closed eyes the complicated hallucinations appeared in the form of corporeal objects surrounding me; the less complicated ones, like, e.g., pictures, microscopic preparations, or ornamental figures, were drawn on the dark ground of the visual field . . . (Kandinsky, 1881, pp. 459–460).

Form-constants and allied phenomena have also been observed by subjects in sensory deprivation situations (Zubek, 1969), following photostimulation (Smythies, 1960; Freedman and Marks, 1965), electrical current (Knoll et al., 1962), crystal gazing (McKellar, 1957; Garvin, 1973), while gazing at a light bulb (Prince, 1939), during migraine scintillating scotoma (Richards, 1971; Aring, 1972), and even during “swinging” or “pendulumlike” motion (Masters and Houston, unpublished manuscript). Many of the geometric forms and designs common to the form-constants were also observed entoptically by Ladd (1892), Purkinje (1918), and many others. Although many investigators have stressed the similarity of drug-induced form-constants and entoptic phenomena (Pokorny, 1969; Barber, 1970; Oster, 1970), there is some evidence that the two phenomena may be quite different (see section on entoptic phenomena). In general, drug-induced patterns appear to be more vivid, more colorful, more regular, and more ornate than those elicited by the other methods.

It has been shown that hallucinatory imagery associated with schizophrenia, epilepsy, and syphilis is somewhat similar to the form-constants of drug-induced states, but the supporting evidence is scant (Plaut, 1913; Leuner, 1962; Malitz et al., 1962). Even the artistic behavior of some schizophrenic patients reflects a “geometromania” in which geometric designs are distorted, exaggerated, and repeated in symmetrical arrangements similar to the designs of cubism (Anastasi and Foley, 1940). The latter cases reflect idiosyncratic content to a far greater extent than those of drug-induced imagery, but the structure of schizophrenic and epileptic imagery suggests many similarities. Indeed, compare the examples of drug-induced imagery already given with the following account of an epileptic seizure:

These were “cartoon-like figures,” pictured in [the patient] mind’s eye as if they were projected on a television screen in close proximity to him. The images were always in black and white, he could “see” them with his eyes open or closed, but he could neither conjure them nor dispel them. They were experienced by the patient as something apart from himself and out of his control (Sedman, 1966, pp. 46–47).

Thus drug-induced visual imagery appears to be similar in many aspects to imagery observed in a wide variety of situations. One might be surprised to find such similarities, but Keeler (1970) has noted that “there are fewer mechanisms than etiologies of hallucinations. There is thus no reason for surprise if different precipitants give wholly or partly similar hallucinatory experiences” (p. 208).



But the form-constants, characteristic of these similar experiences, are only the first stage of a two-stage process of drug-induced imagery. Unfortunately Klüver did not examine the development of imagery past the first stages of mescaline intoxication. Earlier observers (e.g., Knauer and Maloney, 1913; Rouhier, 1927) had noted that the simple geometrical forms give way to landscapes, faces, and familiar objects as the experience progresses to the second stage. Balestrieri (1964) examined drug-induced hallucinations in a group of 50 patients and reported that the elementary forms of the first stage seem to combine with "complex" images, which eventually may replace the forms in the second stage. He thought that such complex images were derived from the activation of images already recorded and retained in the brain. Interestingly, Balestrieri found no differences in the content of LSD-, mescaline-, and psilocybin-induced complex imagery, although it is unlikely that his techniques were sensitive enough to detect any such variation. In a review of more than 500 LSD-induced experiences, Butterworth (1967) noted that certain identical second-stage "symbols" or images recurred both within and between individual patients. Astonishingly, 79% of all the images reported were shared by all subjects. Moreover, between 62 and 72% of the subjects experienced the designs and images that Klüver referred to as form-constants. Of the many "complex" images shared, 49% of the subjects experienced images of small animals or human figures, usually friendly and often in human caricature, whereas 72% experienced religious imagery.

Since this work, there have been few attempts to extend the type of analysis pioneered by Klüver. No one has tried to study the sequential development of the form-constants in a drug experience. There have been no well-controlled investigations of dose-response or time-response relationships, nor any well-controlled studies of the contents of imagery that develops after the initial phase of form-constants. And no attempt has been made to examine other dimensions of visual imagery, such as movement patterns and colors, which may also manifest constancies. Indeed, Klüver had noted that the form-constants were frequently repeated, combined, or elaborated on in various designs, but no consistent patterns or directions of movement were seen. Nonetheless, rotational and left-right horizontal motion were frequently reported by subjects. La Barre (1969) reported that the motion of peyote-induced visual imagery is primarily one of pulsation. Leuner (1964) commented on this movement in LSD- and psilocybin-induced imagery:

On closing his eyes, [the subject] soon sees the brightly coloured whorls of the simple primary hallucinations so often described in the literature of hallucinogens: patches of colour-striped flashes appear; abstract patterns, at first geometrical but later brilliantly coloured, flow lackadaisically, move in myriads, spread in a shower of coloured sparks in a deceptive motion that may take the form of turbulent rushing (p. 2).

Most investigators like Klüver and Balestrieri referred to such movement, color, and second-stage forms as "complex" and did not describe them in detail. It is curiously paradoxical that earlier workers had used similar words in reference to the forms that Klüver himself later analyzed. Klüver attributed this attitude to the novelty of the visions and claimed that observers are often enticed by the color or brightness of the images and ignore the basic forms. They are often awed by the experience and surrender before it as something overwhelming and "indescriva-



ble," causing more than one researcher to use grandiose metaphors and to attribute religious significance and cosmic meaning to visual imagery. But, as Adler (1972) points out: "To attach cosmic meaning to these events is a presumption. We are more likely confronting here the projection of affect onto the outside world. The response that one thinks he recognizes is his own projected and reflected image" (p. 19). This "indescribability" of the form imagery had challenged Klüver to describe it. The apparent complexity of other dimensions challenged us to attempt their description as well. We believed that the study of such phenomena might suggest a typological construct or some common visual imagery underlying drug-induced hallucinations, which could help us understand the etiology of these and related perceptions. It is in this spirit that we began the following experiments.

### IMAGERY IN UNTRAINED OBSERVERS

A series of experiments was designed to investigate the phenomenology of marihuana- and THC-induced visual imagery in groups of untrained observers. Although several of the studies have been reported previously (Siegel, 1971a; Siegel et al., 1972; Miller et al., 1973; Siegel, 1973b), the most current data are presented in this volume.

In our preliminary work, 14 subjects were required to self-administer each of the following drugs in eight weekly sessions. Only one drug was administered in any given session, and the treatment orders were given according to a Latin square design. Each dosage was placed in a 400-mg cigarette, which subjects were required to smoke by inhaling for 5 seconds, holding for 20 seconds, resting for 20 seconds, and repeating the cycle until the cigarette was consumed. The drug treatments were: marihuana: 4.25, 9.41, and 40.0  $\mu\text{g}$  delta-9-THC/lb., b.w.; delta-9-THC on alfalfa: 4.25, 9.41, and 40.0  $\mu\text{g}$ /lb., b.w.; and alfalfa placebo. Each subject in each session gave a five-minute verbal report of his visual imagery at approximately 90 minutes (Trial 1) and 300 minutes (Trial 2) following drug treatment. Prior to the start of each trial, all subjects were dark-adapted and brought into a darkroom in which they sat in a straight-back chair with eyes closed. They were instructed to give a continuing verbal report or running commentary of any visual images or pictures they might see when their eyes were closed. They were asked to pay particular attention to and to report on forms, colors, and movements. The taped-recorded reports were typed and the transcripts analyzed according to the following procedure.

In the scoring procedure, two double-blind experimenters scored each transcript on dimensions of form, color, direction of movement, and action patterns. On each dimension, the frequency of occurrence of each of several categories of verbal responses was noted. The correlation between the two experimenters' sets of scores was  $r = .92$ , and means were used in the analysis of the data. The dimensions, their respective categories, and examples that define them are given below:

#### FORM DIMENSION

*Random.* Blobs, amorphous shapes, blurry patterns, watery patterns with no definite design, etc. (Any form that cannot be classified in the categories below.)



*Line.* Herringbone patterns, zig-zags, polygons, all angular figures without curves or rounded corners, crosses, etc.

*Curve.* Circles, ellipses, parabolas, hyperbolas, sine wave patterns, fingerprint whorls, spheres, balls, scribbling, etc.

*Web.* Spider webs, nets, unsymmetrical lattices and filigrees, veins, etc.

*Lattice.* Lattices, gratings, grids, screens, fretwork, checkerboard, honeycombs, etc.

*Tunnel.* Tunnels, funnels, alleys, cones, vessels, pits, corridors, etc.

*Spiral.* Spirals, pinwheels, springs, etc.

*Kaleidoscope.* Kaleidoscopes, mandalas, symmetrical snowflakes, lacework, mosaics, symmetrical flowerlike patterns, etc.

*Complex.* Any recognizable imagery such as faces, people, landscapes, panoramic vistas, animals, inanimate objects, cartoons, etc.

#### COLOR DIMENSION

Black, violet, blue, green, yellow, orange, red, brown, and white.

(Color responses were scored in the category nearest to the response on the spectrum. For example, maroon = red, tan = brown, purple = violet, blue-green = blue and green, etc.)

#### MOVEMENT DIMENSION

*Aimless.* Any movement without apparent direction, "things floating around," etc.

*Vertical.* Up or down.

*Horizontal.* Right or left.

*Oblique.* Any linear motion at an angle other than vertical ( $90^\circ$ ) or horizontal ( $180^\circ$ ) with respect to the observer's midline axis.

*Explosive.* Motion away from the center, outward from the center, etc.

*Concentric.* Motion toward the center.

*Rotational.* Circular motion, clockwise or counterclockwise, etc.

*Pulsating.* Flickering, pulsating, throbbing, twinkling, etc.

#### ACTION PATTERNS (applies only to complex imagery)

*Complete image changes.* Any complete change of the visual field with substitution of new material for old. This is not to be confused with the development of movement or embellishment of already existing visual imagery. A complete image change usually means a successive transformation from one complex form to another complex form (e.g., "a shark changing into a dolphin changing into a skin diver changing into a submarine" contains four distinct images and three distinct image changes).

*Changes within a single image.* This measure connotes changes within a single image rather than the preceding measure of changes between single images. This can include changes in size or perspective, color changes of the same object, movement changes of the same object, elaboration, etc. A change within a single image usually implies that the image is "doing something" (e.g., "a man is walking down the street and his head gradually swells in size and changes from pink to red, becomes a red balloon, and floats away").



*Combining of images.* Two forms combining to form one (e.g., “a horse and a man combining to form a centaur”). In this case, the horse and man images are not replaced by the centaur image but are “observed” by the subject to actually change or combine through gradual and successive approximations.

*Repeating of images.* This measure implies duplication or multiplication of form (e.g., “one toy soldier is duplicating and becoming a whole army of toy soldiers”).

*Overlaying of images.* This measure implies two distinct forms overlaying one another but remaining separate and independent. In other words, there are two levels of imagery and two different sets of action occurring. For example, a football game is overlayed by a sky full of northern lights and exploding fireworks. Or, more commonly, the subject reports geometric forms overlaying complex imagery.

Some of the results are presented in Table 2 in terms of the total number of visual imagery reports for all subjects in each treatment condition. Note that the number of reports increased dramatically with the increase in dosage of marihuana and THC, although the absolute number of reports in THC sessions was usually higher. The distribution of these reports indicated that normal baseline (no drug) imagery was composed of aimlessly moving black and white random forms with some lines and curves. Only one of 14 subjects reported any complete changes of visual imagery during baseline conditions. Conversely, 6 of the 14 reported a total of 37 complete imagery changes during placebo sessions, marked by complex (58%), random (23%), or curve (14%) forms, which tended to be mostly black, white, yellow, or green. Although movement during placebo sessions was generally aimless (30%), small amounts of concentric, explosive, horizontal, and vertical movements were also reported. The distribution of imagery reports during marihuana and THC sessions showed less random forms than baseline or placebo sessions, as well as slight increases in all other simple forms as dosage increased. Color reports showed a decrease in black and an increase in colors near the red end of the spectrum as dosage increased. Concomitantly, slight decreases in aimless and pulsating movements were reported with increases in more organized motion, particularly explosive and concentric. The actual percentage distribution of complex forms did not change substantially with marihuana and THC sessions (usually approximately 50%), but dramatic changes in action patterns were associated with such imagery. Indeed, changes within a single complete image showed a linear increase with dose, and there were also increases in the combining, repeating, and overlay-

TABLE 2. TOTAL IMAGERY REPORTS FOR ALL Ss IN ALL TRIALS<sup>a</sup> (N = 14)

| Dimension | Baseline | Placebo | M1  | T1  | M2  | T2  | M3  | T3  |
|-----------|----------|---------|-----|-----|-----|-----|-----|-----|
| Form      | 69       | 170     | 248 | 229 | 277 | 290 | 313 | 347 |
| Color     | 94       | 246     | 248 | 291 | 296 | 317 | 327 | 340 |
| Movement  | 17       | 33      | 67  | 68  | 72  | 77  | 84  | 83  |

<sup>a</sup>Adapted from Siegel (1973b). Abbreviations: M = marihuana; T = THC. The numbers 1, 2, and 3 indicate the dose: M1 and T1 = 4.25 $\mu$ g.  $\Delta^9$ -THC/1b; M2 and T2 = 9.41 $\mu$ g.  $\Delta^9$ -THC/1b; M3 and T3 = 40.00 $\mu$ g.  $\Delta^9$ -THC/1b.



ing of images. Generally, the distribution in color, form, and movement reports was relatively the same for THC and marihuana sessions. However, the absolute number of reports for THC sessions was usually greater than marihuana sessions in Trial 2; this suggests a somewhat longer duration of action for the THC treatments. There were only minimal changes in the content of complex imagery as dosage increased. Perhaps the most interesting change reported was the small increase in cartoons and humans.

The most obvious aspect of the findings is that the amount of visual imagery was dose-dependent and increased linearly with increased doses of marihuana and THC. Changes in the distribution of specific forms paralleled changes previously reported for mescaline by Klüver in 1942. Furthermore, *Cannabis*-induced changes in color and movement of imagery suggest the presence of hallucinatory constants in these dimensions. The most apparent color constant was red, and the most apparent movement constant was explosive and concentric motion.

**Phenomenology.** The previous analyses of form, color, and movement reports did not reflect the exact nature of all the hallucinogenic constancies. One reason appeared to be that most subjects experienced difficulty in verbally describing their visual imagery. Careful analysis of the transcripts revealed that *Cannabis*-induced visual imagery was reported to be like a movie or slide show projected in front of the subject's eyes. This finding is similar to hypnagogic imagery, which has also been described to be like "a series of images which pass across my field of vision from right to left as if projected from a magic lantern that is being rotated" (McKellar, 1957, p. 39). In companion studies we have determined that there were no significant differences between eyes-closed imagery and eyes-open imagery when the latter occurred in a dark and lightproof room. Although many of the subjects could not label simple forms, they frequently acknowledged "geometric forms of all kinds" to be present.

Such imagery was often characterized by a very bright light in the center of the visual field (Fig. 4) which obscured central details but permitted imagery on the periphery to be observed. The locus of this point of light probably created a tunnel-like perspective, and subjects reported viewing much of their imagery in this regard (Fig. 5). The tunnel perspective probably contributed to the reports that imagery tended to pulsate and move toward the center of the tunnel (concentric movement) or move away from the center light in the tunnel (explosive), or both. When imagery appeared colored, all colors of the spectrum were reported although the incidence of red increased with dosage. Figure 6 (see color section) illustrates a blue lattice-tunnel reported by many subjects during the first stages of marihuana or THC intoxication. As the experience progresses, this tunnel appears red. Complex forms tended to change rapidly and often in associative ways (Fig. 7). Indeed, so rapid was the flow of imagery that most subjects found it difficult to maintain a running commentary on these events. Nonetheless, such imagery reports of recognizable scenes, people, and objects reflected characteristic symmetry, often in caricature or cartoon form, with some degree of depth. Numerous examples of distinctive memories occurred, and these were projected onto the visual field, often overlaid by the form-constants. We have chosen to illustrate some of these properties with examples from studies with *Cannabis* derivatives, commonly considered weak hallucinogens, and from studies with



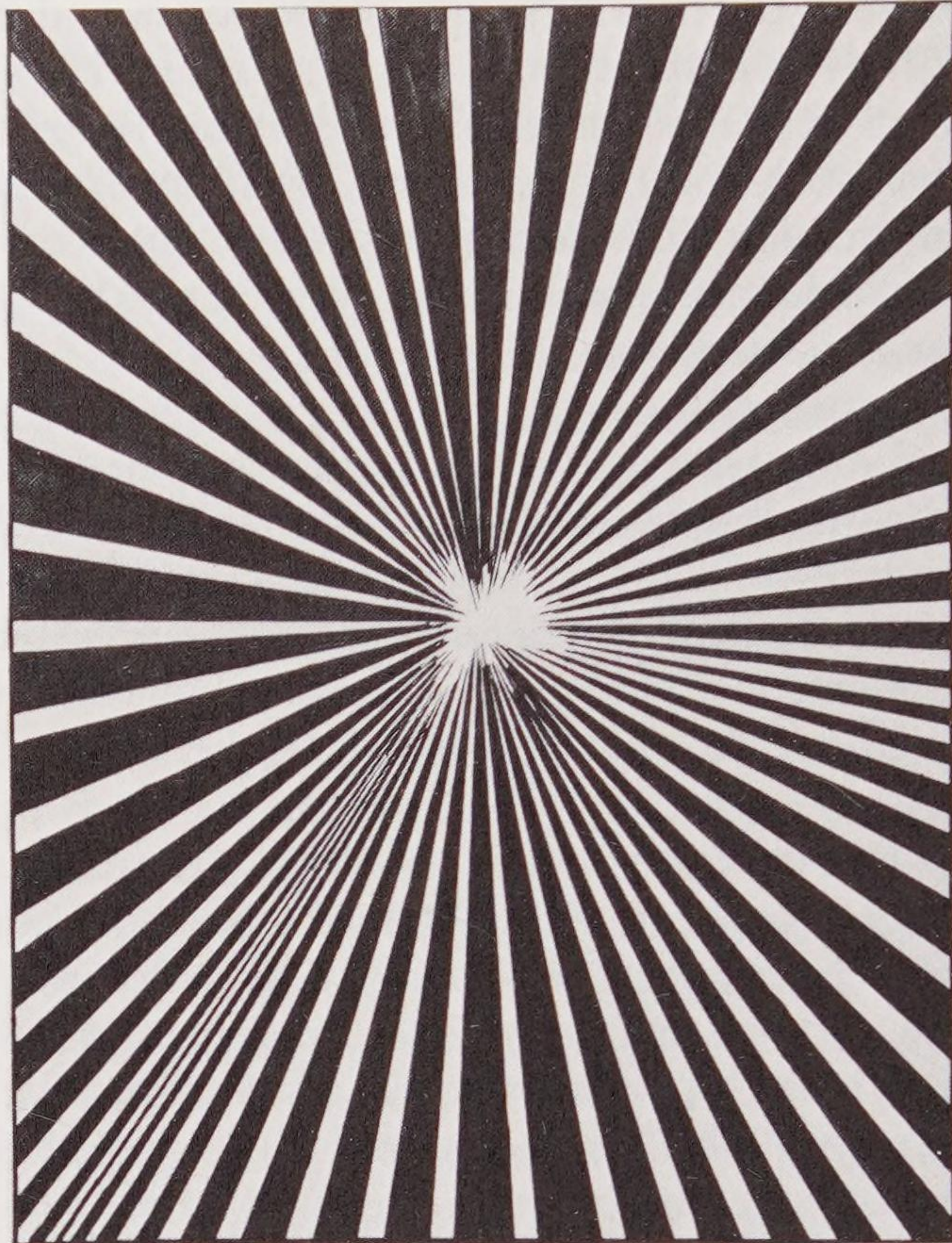


**Figure 4** Bright light in center of the visual field reported during early stages of *Cannabis* intoxication. Drawing by Sheridan, pen and ink.

ketamine hydrochloride, recently recognized as a potent hallucinogen (Doenicke et al., 1969; Rumpf et al., 1969; Reher, 1971; Collier, 1972). The *Cannabis* reports are from the previously described study (Siegel, 1971a) and the ketamine reports are from an identical companion study with that compound (Siegel, Lebowitz, and Jarvik, unpublished data). All ketamine dosages were 1 to 2 mg/kg, i.v.

#### MOVIE OR SLIDE SHOW FORMAT WITH RAPID FLOW OF IMAGERY

Everything's changing really fast, like pictures in a film, or television, just right in front of me. I am watching it happen right there. (ketamine)

In fact, the scenes in my head are very real. I mean if you get right into it it's as though you are there sort like a movie or something. It looks in a way like a movie. They're surrounding all around. (THC)

... people standing in the office, appearing like slides crossing my field of vision. (marihuana)

#### TUNNEL PERSPECTIVE OF IMAGERY

I'm moving through some kind of train tunnel. There are all sorts of lights and colors,



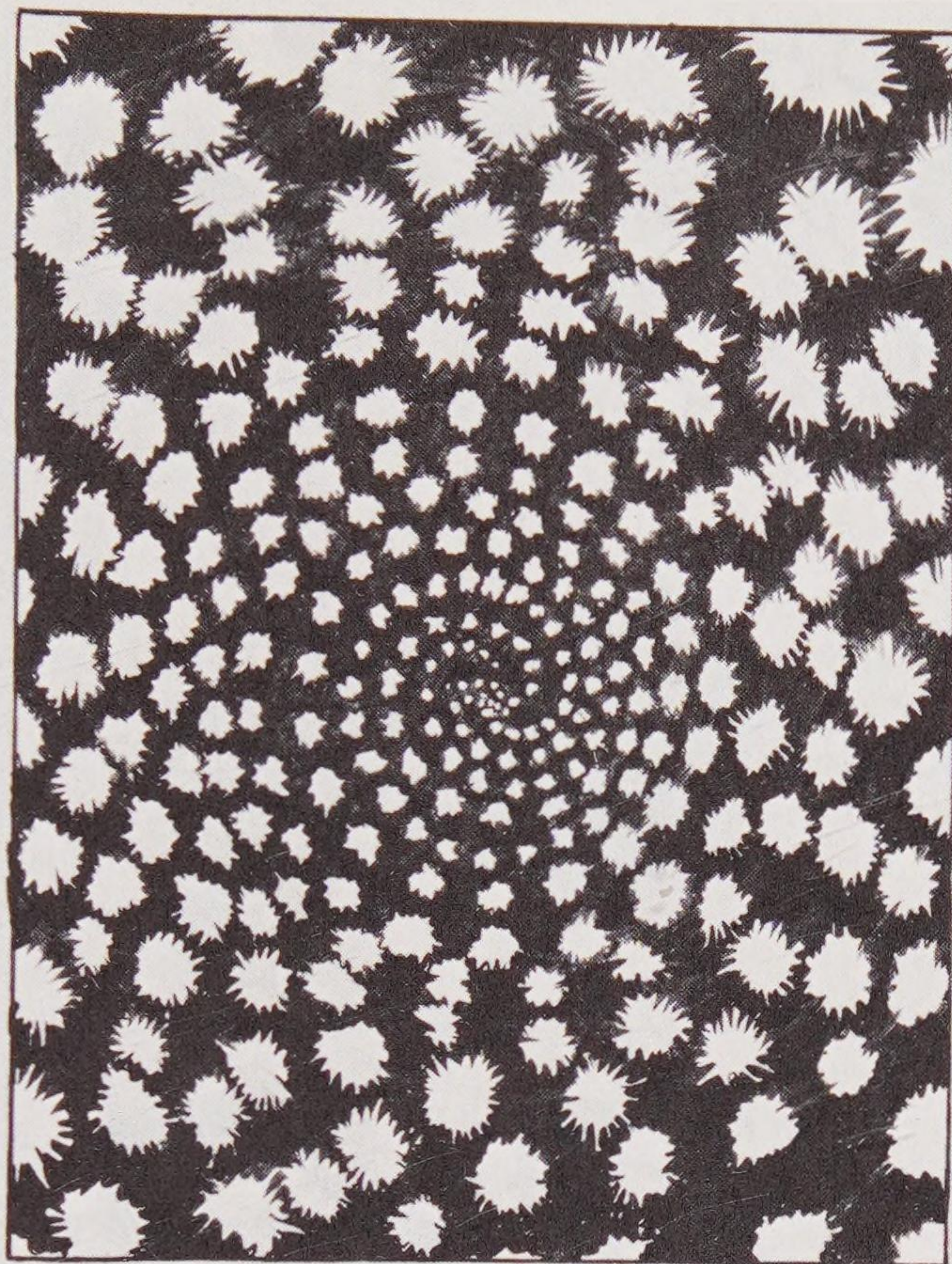


**Figure 5** Pulsating spiral-tunnel reported as *Cannabis*-induced imagery constant. Drawing by Sheridan, pen and ink.

mostly in the center, far, far away, way, far away, and little people and stuff running around the walks of the tube, like little cartoon nebishes, they're pretty close. (ketamine)

It's sort of like a tube, like I sort of feel—like sort of—that I'm at the bottom of a tube looking up. You can see the slides [imagery] converging with a point in the center. (THC)

It's better described as if I was traveling through the inside of a tube and the background faded towards the center of the tube and so that all of it seems to be going from behind, below, over, above me and down towards my feet again and just like a circular motion. . . . I am traveling into a tunnel and out into space. (marihuana)

#### SIMPLE GEOMETRIC FORMS IN IMAGERY

Checkers, changing red checkers. Oh, I'm getting pinwheels. It's like a horseshoe shape, now it's gone. Now it's got stripes. Two, there's two spots, oval shapes, they're outlined in white. (ketamine)

There's like a honeycomb in the background, like a real honeycomb. And it's kind of moving from me. (THC)

There are a lot of intense little geometric figures over a mess of coke. (marihuana)



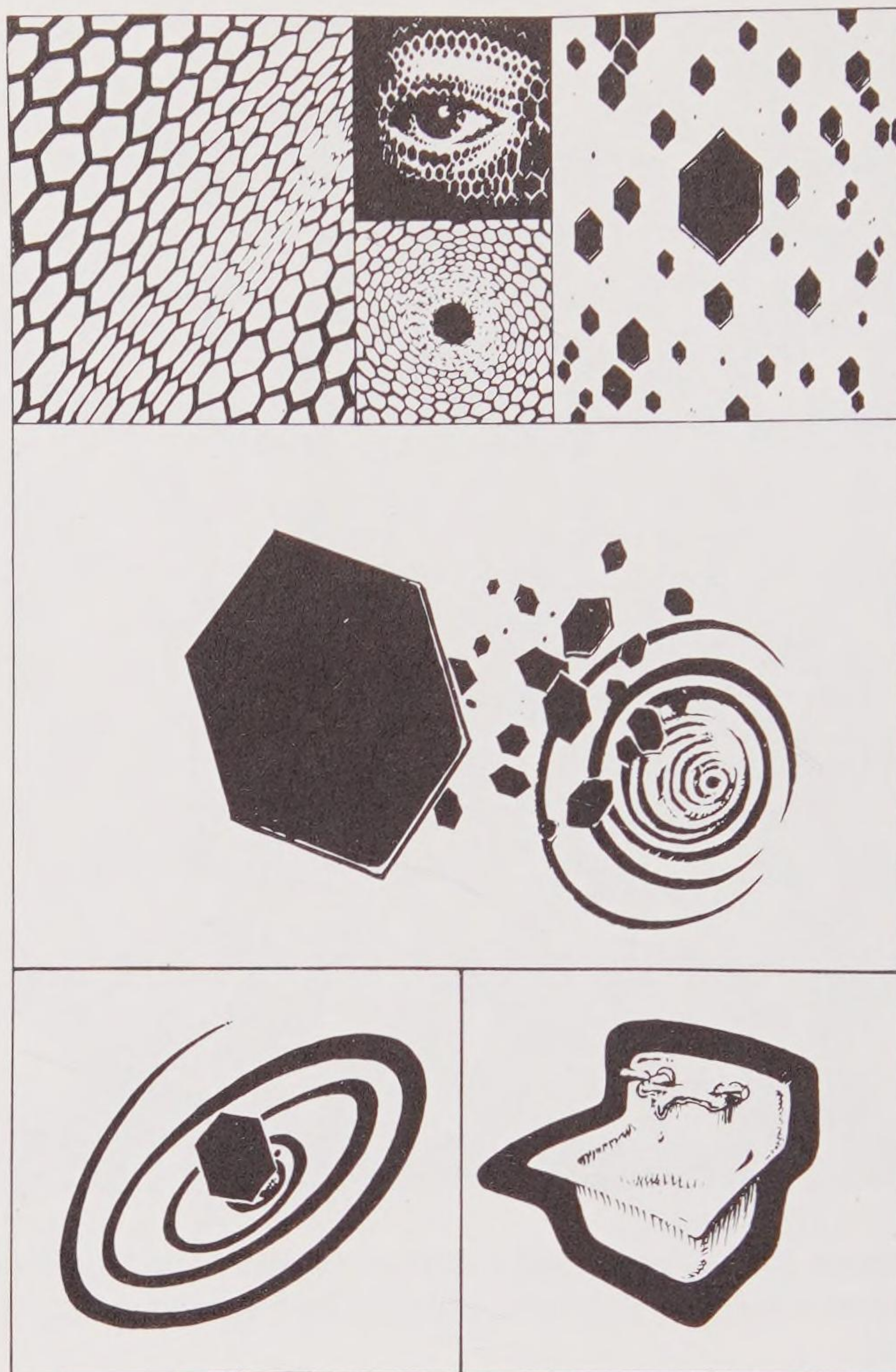


**Figure 7** Illustration of associative changes in complex THC-induced imagery. Subject actually reported: "And then my eyes again, a hexagon, a little hexagon—whoa—here comes a big hexagon! He is pushing those little hexagons aside because he doesn't fit. My God! He split up the whole, all the little hexagons are going out to the right, all out the funnel, they all disappeared, nothing left but a plastic sink." Drawing by Sheridan, pen and ink.

#### COMPLEX FORMS WITH RAPIDLY CHANGING ASSOCIATIONS IN IMAGERY

Now I see a woman's face and she's got real big eyes and I don't see part of her hair, and her hair is gold. And there's a grandfather clock, it's more like a toy not a real one. Now I see an old man and he's lying on his back, now he is bending down and he's picking something up. (ketamine)

There was some kind of insect which changed to a salamander which changed to an outline of a toad. Now, it's changing quickly and I don't know what it is. (THC)

Now I can see flowers. Now it's like a bird. Like a pretty ostrich, a white ostrich with a purple crown around his head, walking and flapping its wings and now it turned into a donkey carrying somebody on his back. At first it looks like Christ and then it looks like Indians riding around a horse. It's a horse now and it's getting closer and closer and breathing very heavily and riding very hard. (marihuana)



## MEMORY IMAGERY

I can see a movie that I saw recently, *2001*. Hey, this is really groovy! Really groovy! It's like it's right there and I'm seeing it all over again. The spaceships, the space station, floating through space, it's all so vivid and real. (ketamine)

. . . the house, like inside a house and it's the house where I grew up and it's the stairs I used to go upstairs into the hall, and I can see it all. And there's the kitchen, and there's my mother. She's wearing her nursing uniform. She's sad cause she's so . . . doesn't seem strange . . . as if I'm back in the past, as if I never was in the house, as if I never belonged there, and it's like a summer day in Regina, very clear blue skies, just how things were when I was about 13 years old I guess. (THC)

I am living in the past, and now I'm at where I broke my two teeth swinging on some bars outside synagogue, in a synagogue where you hang up your clothes, and I thought the chair was underneath me, but my friend had taken the chair away to get up on it himself and I just fell down, fell, flat on my face and started yelling and screaming and everybody came out of the church, and I'm screaming. I mean out of the synagogue, out of the chapel, and like I was seeing them, you know, the cuddling and the—I don't know—and I am bawling my head off. I am so much in pain. (marihuana)

## IMAGERY IN TRAINED OBSERVERS

A series of studies was designed to investigate the phenomenology of drug-induced imagery in trained and untrained observers. A preliminary report of some of these findings has appeared elsewhere (Siegel, 1973b), but some data are presented here for the first time.

**Development of method.** Previous reports of drug-induced visual imagery suggest that these events were as dissimilar as they were similar. Subjects differed widely in their choice of words to describe phenomena. Form, movement, and color constants did emerge from these different reports, but the imagery was riddled with idiosyncratic experiences. For example, one subject continually experienced unbidden images involving sexual fantasies with the experimenter, and another subject reported recurring images of the hospital in which the experiment was conducted. Most subjects were unable to communicate various aspects of the imagery such as the precise geometric forms or directions of motion, and would comment: "I'm seeing things I can't describe" or "I don't know what they are and don't know how to explain them." In addition, the rapid flow of images interfered with verbal reporting for many subjects: "There's a lot happening. It's constantly changing all the time. It's very difficult to keep up with what's appearing and disappearing."

Similarly, McKellar (1957) observed that when his subjects tried to convey the nature of complex or novel experiences, such as mescaline-induced hallucinations, they often found it necessary to introduce many new words. McKellar referred to such words as experimentally produced neologisms, not sanctioned by literary or scientific canons. Since these words possess a purely private meaning, being understood by the subject and no one else, they are useless and misleading as vehicles for communication. For example, McKellar encountered neologisms such as "quadrupus," a newly coined word referring to some type of animal, and "pink"—a new use of this word to describe a bright red car.



One approach to overcoming this problem of inefficient and individualized reports would be to pretrain observers in a standard method for rapid imagery identification and reporting. Such an approach was indirectly advocated by Tart (1971), who maintained that consensual validation of internal phenomena (e.g., imagery) might be possible with trained observers. Indeed, Lilly (1970a) proposed that a new language be established for the sharing of and agreeing on the nature of such subjective experiences. This new language or code would have to satisfy several important requirements.

1. The code must utilize an operant response, the rate of which would not be impaired by the experience to be reported.

2. The code must be empirical and derived from the actual verbal reports of imagery rather than from a theory that is applied to the material (cf. Hall and Van de Castle, 1966).

3. The code must include physical standards to which observers can compare their reports.

4. The code must allow observers to anticipate novel stimulus events and classify them with confidence and reliability. Indeed, as B. F. Skinner (1971) cautioned "... even a carefully trained observer runs into trouble when he studies new private stimuli."

In meeting requirement (1) we were guided by the pilot studies conducted by Timothy Leary (1966b, 1966c) as well as the basic research of Ogden Lindsley and his co-workers (Lindsley, 1957; Lindsley et al., 1961; Lindsley and Contran, 1962). Throughout his many studies with hallucinogens, Leary noted that drug-induced imagery often "defies external metaphor." Instead of using objective physical standards, he recommended the use of experienced (trained) subjects who could compare phenomena between and within drug sessions. Leary used the operant key press as his report and equated it to the occurrence of a subjective state. For example, in the case of an hallucination, the verbal report of "I saw it" or "I heard it" was equated to a key press. This particular equation and procedure has been used by other investigators in the study of hallucinations (cf. Hefferline et al., 1973).

Indeed, Lindsley and his colleagues had already demonstrated that operant behavior provides a continuous and objective method for the study of gross behavior in such altered states of consciousness as anesthesia, coma, and sleep. However, a method for obtaining detailed information regarding subjective phenomena in these states had not been developed until Leary collaborated with Lindsley and developed the "experiential typewriter." This apparatus consisted of a 20-key typewriter connected to a recording instrument. The keys were used to code various subjective states including modes of perception, internal images, external images, eyes-closed and eyes-open experiences, hallucinations, and colors. The subjects were pretrained by simply having them memorize the experiential categories and their corresponding keys. When a subject felt a bodily sensation such as "pain," he would press a specific key to signify this event. Similarly, the experience of oscillating colors could be signified by pressing a different key. The locus of this particular hallucination in terms of eyes-open or eyes-closed imagery could be signified by simultaneously pressing yet another key. The



device recorded the occurrence of these events as a function of time. In preliminary trials with LSD and DMT, Leary found that the ataxia associated with these drugs interfered with the simple motor task of depressing the typewriter keys, and continuous experiential reporting was not always possible. This problem might have been circumvented if minimal dosages had been employed. In addition, the key press could have been replaced by a verbal operant, since Leary found that this was the only useful technique for continuous reporting. Therefore we decided to develop a verbal code for the reporting of drug-induced hallucinations.

Requirement (2) was fulfilled by data derived from the previous study of imagery in untrained subjects. On the basis of this material it was possible to construct a list of eight forms (random, line, curve, web, lattice, tunnel, spiral, kaleidoscope), eight colors (black, violet, blue, green, yellow, orange, red, white), and eight movement patterns (aimless, vertical, horizontal, oblique, explosive, concentric, rotational, pulsating), which the subject could use in describing visual imagery.

Requirement (3) called for a matching of reported events to physical standards. This is a standard procedure employed in many perceptual and psychophysical experiments, and its application to imagery measurement has been advocated by Segal (1972):

... in both instances [perception and imagery] the observer reports on the phenomenological experience and the neural substrate is obscured. The main difference is that the perception is characterized by the presence of a clearly defined physical stimulus against which verbal report or other behavioral measures can be scaled, but no clearly relevant external stimulus characterized the images. However, if the image could also be matched against the objective standard of a physical stimulus, then it could be measured in much the same way (p. 204).

Both requirements (3) and (4) were fulfilled by pretraining subjects in concept-formation procedures whereby reports could be matched to previously learned categories, which were defined by physical standards but allowed for broad generalization within categories.

Human observers can learn to code complex stimuli or visual perceptions into categories, thus simplifying the environment to some degree. Many psychologists think of such learning as concept formation (cf. Bourne, 1966). Concept formation allows man to code features into categories and to respond to all instances of the features in the same way; otherwise learning would be overwhelmingly complex, since the observer would be forced to deal with each individual perception as an unique event. Thus learning of categories to respond to restricts the number of response alternatives and facilitates the observer's reporting. He is said to "abstract" or to "generalize." The effect of controlling the learning of such generalizations in the laboratory is to specify the precise accuracy with which they will be applied to new stimuli (i.e., drug-induced imagery) never before encountered by the subject.

In the type of concept-formation training used in the study of drug-induced imagery in trained observers (Siegel, 1973b), stimulus displays consisting of 35mm slide transparencies were presented to the subjects. Only one display was presented on any given trial. The displays differed from trial to trial, and the



subject was required to make one response in the presence of one stimulus and another response in the presence of another stimulus. Usually, responses in the presence of positive stimuli can be rewarded, whereas negative stimuli are presented while extinction is in effect. This type of successive discrimination is often referred to as a go/no-go discrimination. However, in the conditional successive discrimination used by Siegel (cf. Siegel, 1970a), it is possible for a subject to make a correct response and obtain a reward (verbal statement of "correct" from experimenter) on each trial.

A notation for the application of these procedures to the Siegel study may be helpful. Consider the concept-formation paradigm where  $T$  represents a class of stimuli containing the distinctive form feature "tunnel." Since  $T$  features change from trial to trial, a suitable notation becomes  $T_1 \dots T_n$ . In effect, the subject never encounters a constant or invariant  $T$ , and he must learn to abstract or to generalize to select correctly from among the many displays. In the actual training procedure, subjects were rewarded for verbal responses of "tunnel" to displays containing some instance of  $T$  but were never rewarded for responses of "tunnel" to displays with  $T$  features absent. However, there was always an appropriate response available to the subject for all displays seen. Thus when "tunnel" was judged inappropriate, the subject would be required to select another feature present in the displays, such as "spiral" or "lattice."

Twelve subjects, between the ages of 21 and 30, were used. Although all subjects had previous recreational experience with hallucinogens, three had never experienced drug-induced visual imagery prior to entering the experiment. Subjects were randomly assigned to three groups of four each (each group included one subject who had not had previous drug-imagery experiences). In Group A (trained subjects), subjects received daily sessions of concept-formation training on form, color, and movement dimensions.

Each training session consisted of 72 successively presented 35mm slides including three trials of each of the 24 categories (eight each of forms, colors, and movements), all randomly alternated. Examples of the training slides used in the form dimension are given in Fig. 8. Slide material for the color categories was compiled from the 267 color name pockets of the Inter-Society Color Council and the National Bureau of Standards (ISCC-NBS) color-naming system, as well as numerous Kodak Wratten filters. Slide material for the movement patterns was constructed from rotary-polarized materials according to a previously described procedure (cf. Siegel, 1970b; Siegel, 1971b).

Briefly, the principle of rotary polarization allows apparent movement to be displayed in conventional 35mm slides and is similar to that used to achieve motion in animation techniques. For example, it is similar to techniques employed by many television meteorologists to depict rain or snow "moving" on local areas of weather maps. It is also similar to motion produced by the flicker of neon lights, such as "arrows" directing customers to a particular commercial establishment.

In the training sessions, subjects were required to identify each slide's category with a correct verbal response before they could advance to the next trial. Incorrect responses resulted in repeat of the trial until there was a correct response. The slides presented during a session all differed from one another, and different sets of slides were presented in each session. Trial length was gradually shortened from 15 seconds to 8 milliseconds, and the intertrial interval was reduced from an initial 10 seconds to 1 second, to simulate the rapid changes reported in the



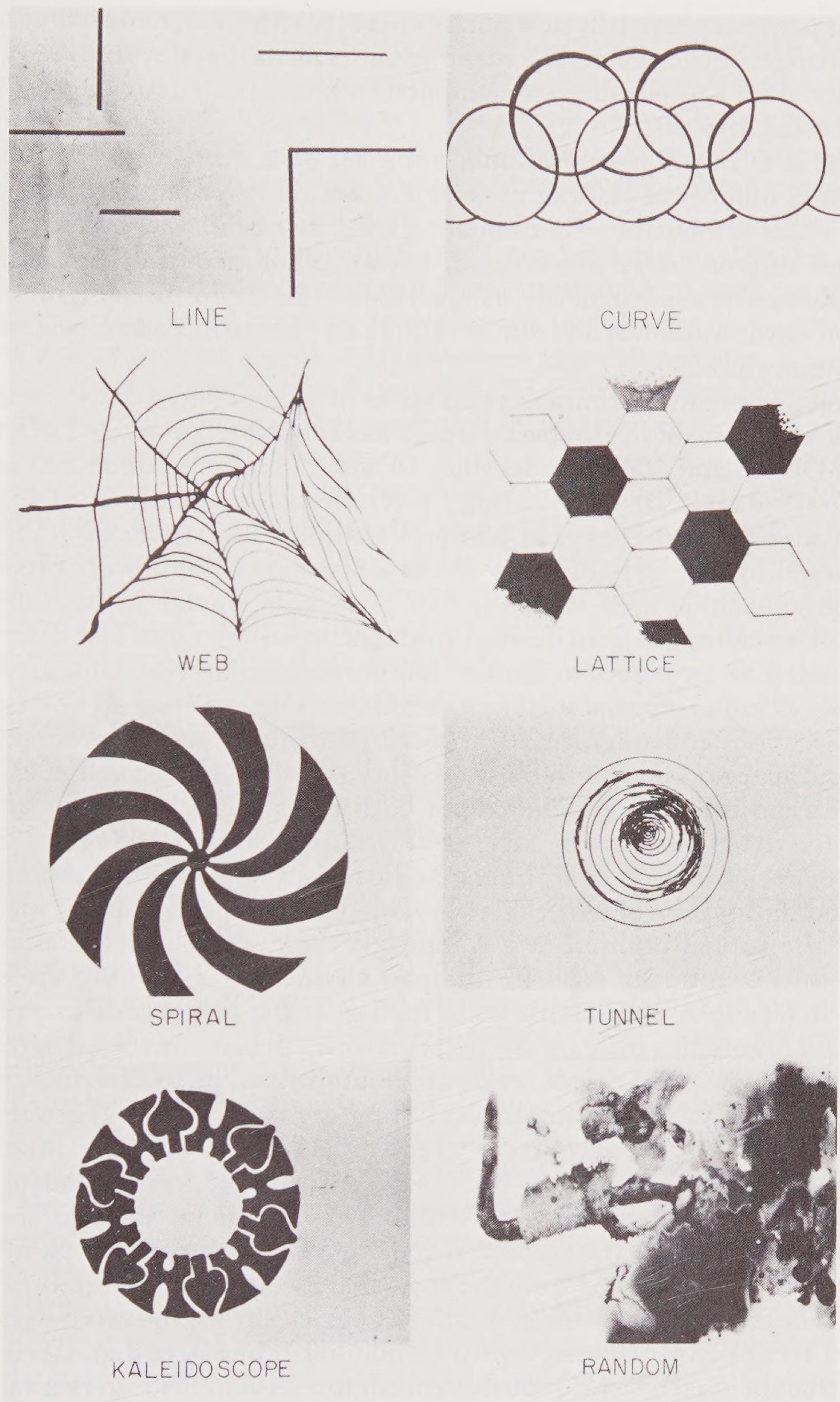


**Figure 8** Sample slides used in form dimension training of human observers.

previous study with untrained observers. Subjects were trained until five successive sessions without error had been achieved; all subjects reached this criterion after 20 training sessions. To handle unique combinations of forms, colors, and movements that may not have been anticipated by the training procedure, subjects in Group A received five additional sessions of concept-formation training on



the action patterns previously described. These patterns included changes within images, changes between images, repeating patterns and overlaying patterns. The slide material for this training was compiled from the polarized material used in the movement displays.

Subjects in Group B (pseudotrained subjects) were exposed to the same slide material and number of sessions as Group A, but they were instructed to simply view the slides without any discrimination training per se. Subjects in Group C (untrained subjects) were not trained. A companion group of two additional subjects (Group D) was instructed to simply memorize the form, color, movement, and action words without actual slide training and without any additional explanation of these words.

All subjects were then administered a series of single-blind weekly test sessions in each of which one of the following drugs was administered orally: LSD, 50 and 100 $\mu$ g; BOL, 50 and 100 $\mu$ g; psilocybin, 10 and 20 mg; mescaline, 200 and 300 mg; delta-9-THC, 10 and 20 mg; phenobarbital, 30 and 60 mg; and *d*-amphetamine, 5 and 15 mg. In addition, marihuana (2.8% delta-9-THC) was administered by having the subject smoke a 500 mg cigarette with a fixed time inhalation-exhalation cycle until the first onset of a change in baseline visual imagery. These dosages were derived from preliminary studies that determined the minimal dose necessary to induce changes in baseline visual imagery. Since high doses of hallucinogens such as mescaline can incapacitate an observer and impair psychophysical judgments (Karwoski, 1936), the doses here were necessarily low and had no known effects on sensory thresholds (Caldwell et al., 1969, 1970). Placebo trials were included for each drug listed, as well as an initial baseline (no drug) session. For subjects in Groups A, B, and D, regular training sessions or memorization drills intervened between weekly drug sessions.

After administration of the drug, each subject in Groups A, B, and C was placed alone in the supine position in a completely dark, soundproof chamber and instructed to continually report eyes-open visual imagery during the session. Subjects in Group A were restricted to the use of the verbal code except in the description of complex imagery. Subjects in Group D were instructed to recite the memorized list of verbal responses throughout the session, to determine what, if any, preferences subjects manifest in reciting the code words. The test session terminated at the subject's request or when verbal reporting reached low operant levels. The average session was six hours. All subjects were asked to give a subjective rating of their "high" on a 0 to 7 point scale at variable 15-minute intervals throughout the test session. When this rating indicated a peak subjective high, subjects were removed from the room and escorted to an outdoor botanical garden. There the subjects wore blindfold goggles, lay supine on the grass, and reported eyes-open visual imagery for 15 minutes. They were then taken back to the test chamber, and dark-adapted, to finish the session. Prior to reentering the chamber, subjects in Group A were tested for accuracy of performance in the concept-formation tasks with new concept slides never before seen.

**Results and Phenomenology.** In experiments of this scope and magnitude it is always difficult to decide which of the copious data to discuss. Here we give results that support the use of trained observers as well as the results obtained from that group of subjects.



The distribution of simple form reports for each group of subjects throughout the first 120 minutes of the smoked marihuana sessions is presented in Fig. 9. The simple forms reported here represent 67% of the form reports for all subjects; the remaining 33% were complex imagery. The distribution of form reports during baseline sessions (in mean percentages) appears on the graphs in Fig. 9 at time 0. The distribution of form reports (in mean percentages) following treatment with marihuana appears along the postdrug axis in blocks of 15 minutes. The distribution of these reports for trained subjects indicates that there is a shift from baseline random and curve forms to lattices and tunnels within 15 minutes postdrug, with maximum change at 30 minutes. Interestingly, this change corresponds to the subjects' self-reports of a peak subjective high after 30 minutes. This distributional shift starts to reverse after 90 minutes and returns to near-baseline levels by 120 minutes. Concomitantly, there are small increases in reports of kaleidoscope forms, an example of which is presented in Fig. 10. Combinations of forms were frequently reported, and the most common of these—repeating curved lines in a tunnel-like arrangement—is illustrated in Fig. 11. Although it might be argued that extensive exposure to training slides influenced reports in this group of subjects, the concept-formation procedures provided for equal exposure to all eight form categories. Thus there would be no reason to expect this skewed distribution to occur during drug sessions. Indeed, subjects in the pseudotrained group received equal exposure to the training stimuli and they also manifested this shift, albeit smaller, to lattice-tunnel forms, as did the untrained subjects who did not view slide material (Fig. 9). Furthermore, subjects in Group D showed neither sequential dependencies with the code words nor preferences for any groups of words such as lattice-tunnel.

The curves for the trained subjects were based on significantly more reports than the other groups. For example, the average rate of imagery reports per minute (rpm) in the 120-minute marihuana sessions was: Group A, 20 rpm; Group B, 6 rpm; and Group C, 5 rpm. In addition, the inter-observer variance was high in all groups except Group A, which demonstrated the most significant shift to lattice-tunnel forms. The trained subjects, however, were not impaired in concept-formation ability during hallucinogen sessions, since only the 60 mg dose of phenobarbital significantly disrupted performance in both concept and color-naming tasks. The latter result is somewhat surprising, since doses of THC as low as 7.2 mg impair concept formation as measured by a category test (Konoff et al., 1973). Nonetheless, many trained subjects showed increased reaction times in performing concept tasks during hallucinogen sessions. This effect may be caused by momentary lapses of attention (Moskowitz et al., 1972) or changes in retrieval processes dealing with short-term memory (Darley et al., 1973).

Figure 12 shows the distribution of form, color, and movement reports for trained subjects, averaged over each six-hour high-dosage drug session, including a placebo session. In general, the low-dosage treatments resulted in similar distributions but with a greatly reduced number of imagery reports. From Fig. 12 it is clear that treatment with placebo, BOL, phenobarbital, or *d*-amphetamine did not significantly alter the normal baseline distribution of form imagery. Conversely, the hallucinogens THC, psilocybin, LSD, and mescaline induced a significant and dramatic shift to the lattice-tunnel forms, as seen in the earlier marihuana data (Fig. 9). The shift here occurred between 90 and 120 minutes after ingestion and



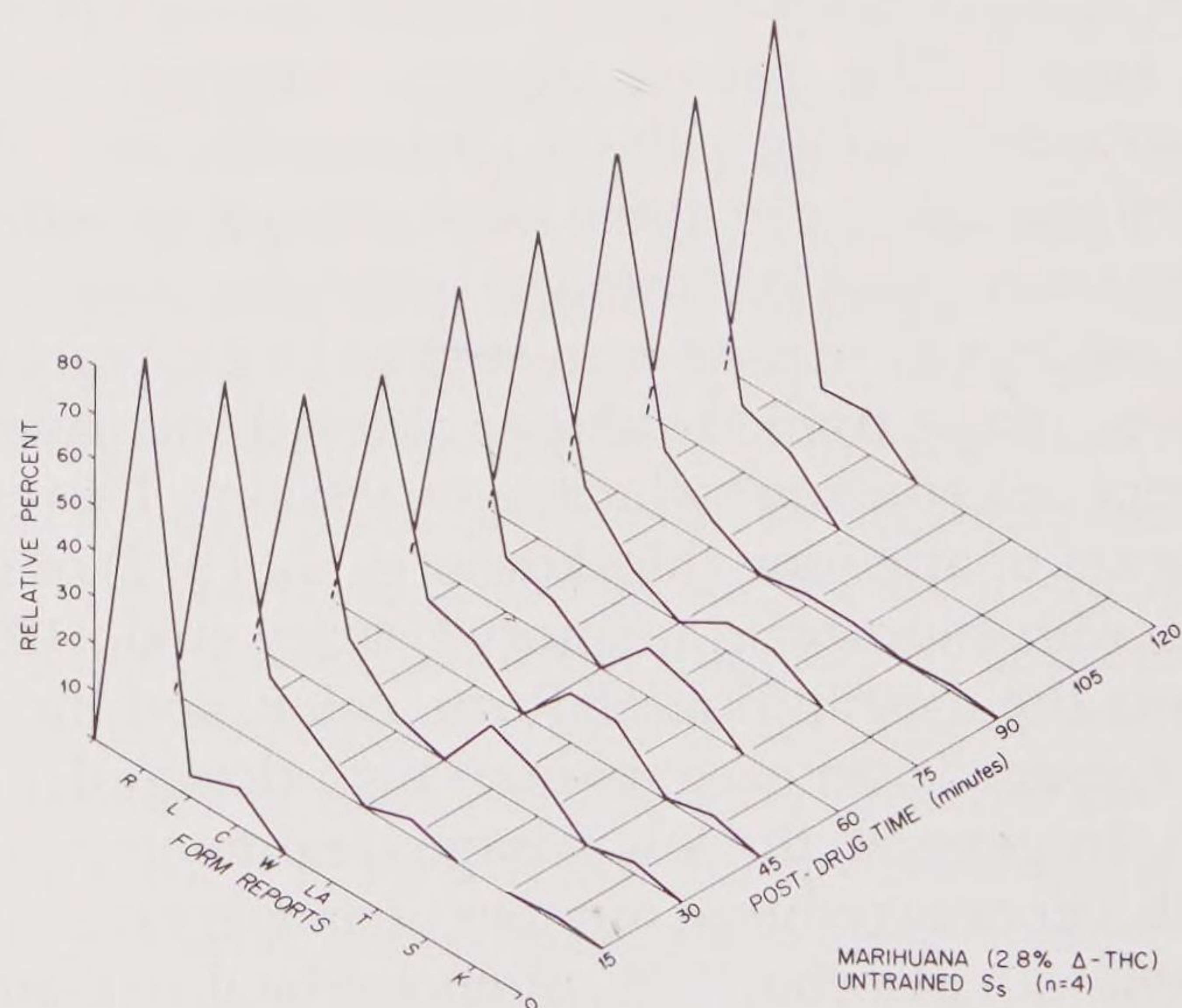
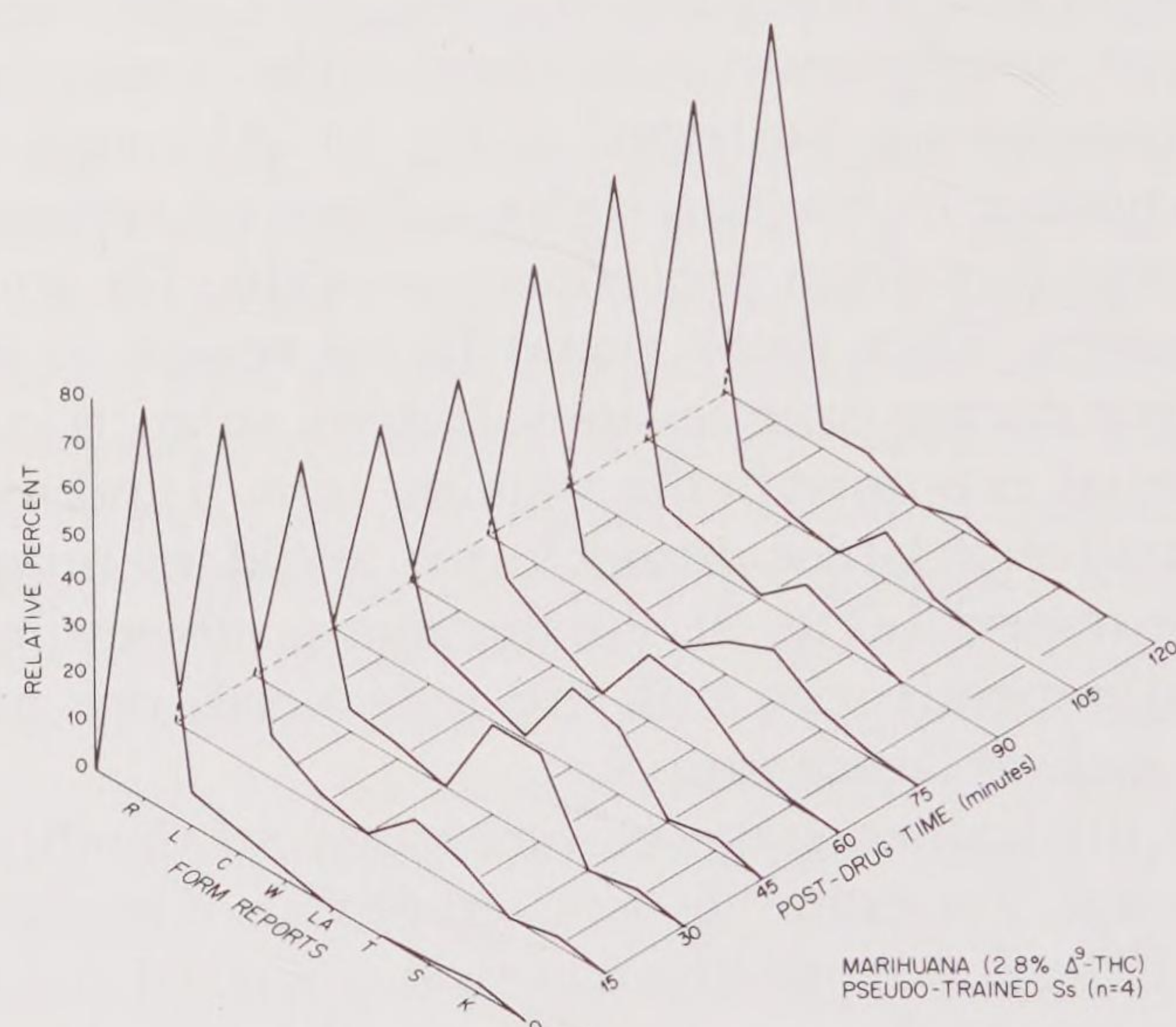
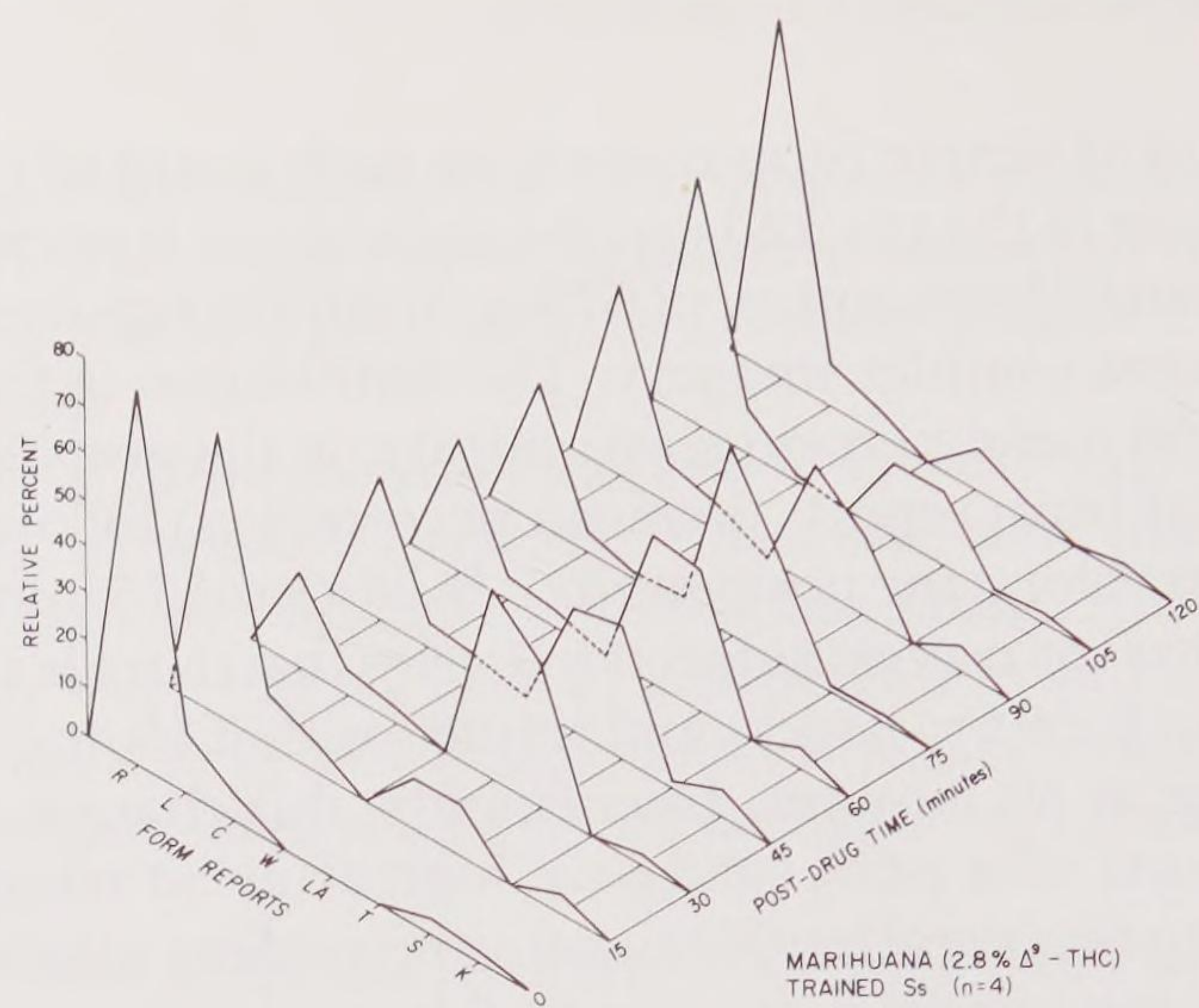


**Figure 9** Percent distribution of form reports for each group of subjects for predrug baseline (0) and postdrug blocks of 15 minutes following inhalation of marihuana. R = random, L = line, C = curve, W = web, LA = lattice, T = tunnel, S = spiral, and K = kaleidoscope.



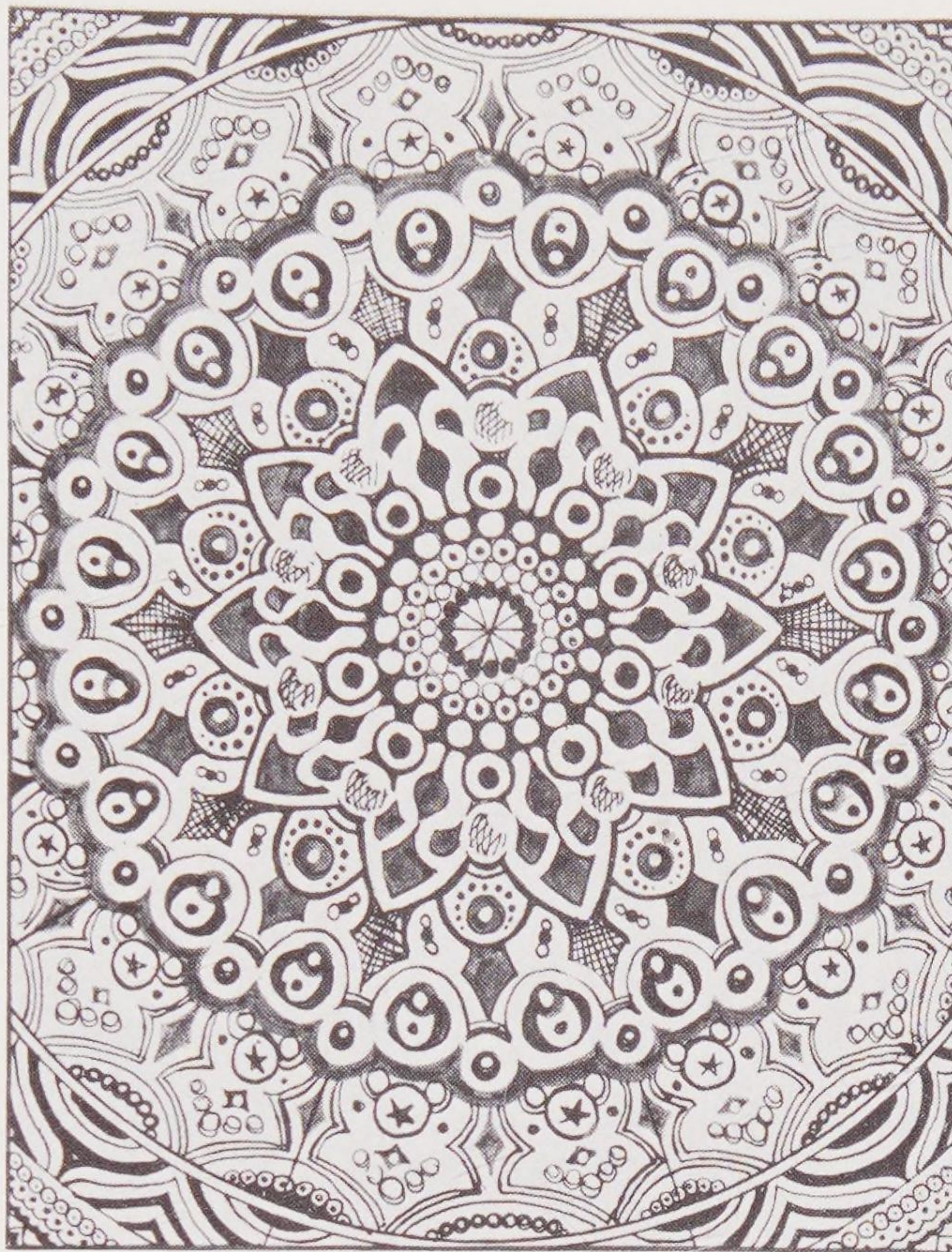


**Figure 10** Kaleidoscopic form pattern reported during marihuana-induced imagery sessions. Drawing by Sheridan, pen and ink.

was probably related to the slower absorption of the drugs following the oral route of administration. The distribution of color reports in Fig. 12 shows a parallel shift from the black, violet, and white colors, which characterize baseline imagery, to red, orange, and yellow during hallucinogen sessions. The single exception was THC, which produced significantly more blue reports than the other drugs, and these may be related to the lowered oral temperature found in some subjects treated with THC (Hosko et al., 1973). However, Marshall (1937) noted that the shorter wavelengths of light, particularly blue, characterized the initial phase of mescaline-induced hallucinations. Indeed, early color reports by subjects in hallucinogen sessions indicated much blue, and this may be related to the hypothermia induced in animals by such drugs (Ladefoged, 1973). The distribution of movement reports in Fig. 12 indicates an hallucinogen-induced shift from the aimless and pulsating patterns of baseline sessions to more organized explosive and rotational motion. However, the subjects did note that the pulsating motion was characteristic of all imagery movement (e.g., "No matter what else the imagery is doing, no matter how it's moving, it's always pulsating, always flickering and this is the *basso continuo* of its motion.")

Complex imagery usually did not appear until well after the lattice-tunnel shift was reported. At that time, the complex forms constituted between 43 and 75% of the total form reports of trained subjects during hallucinogen sessions. Such images first appeared in the reports as overlaying the lattices and tunnels (Fig. 13,



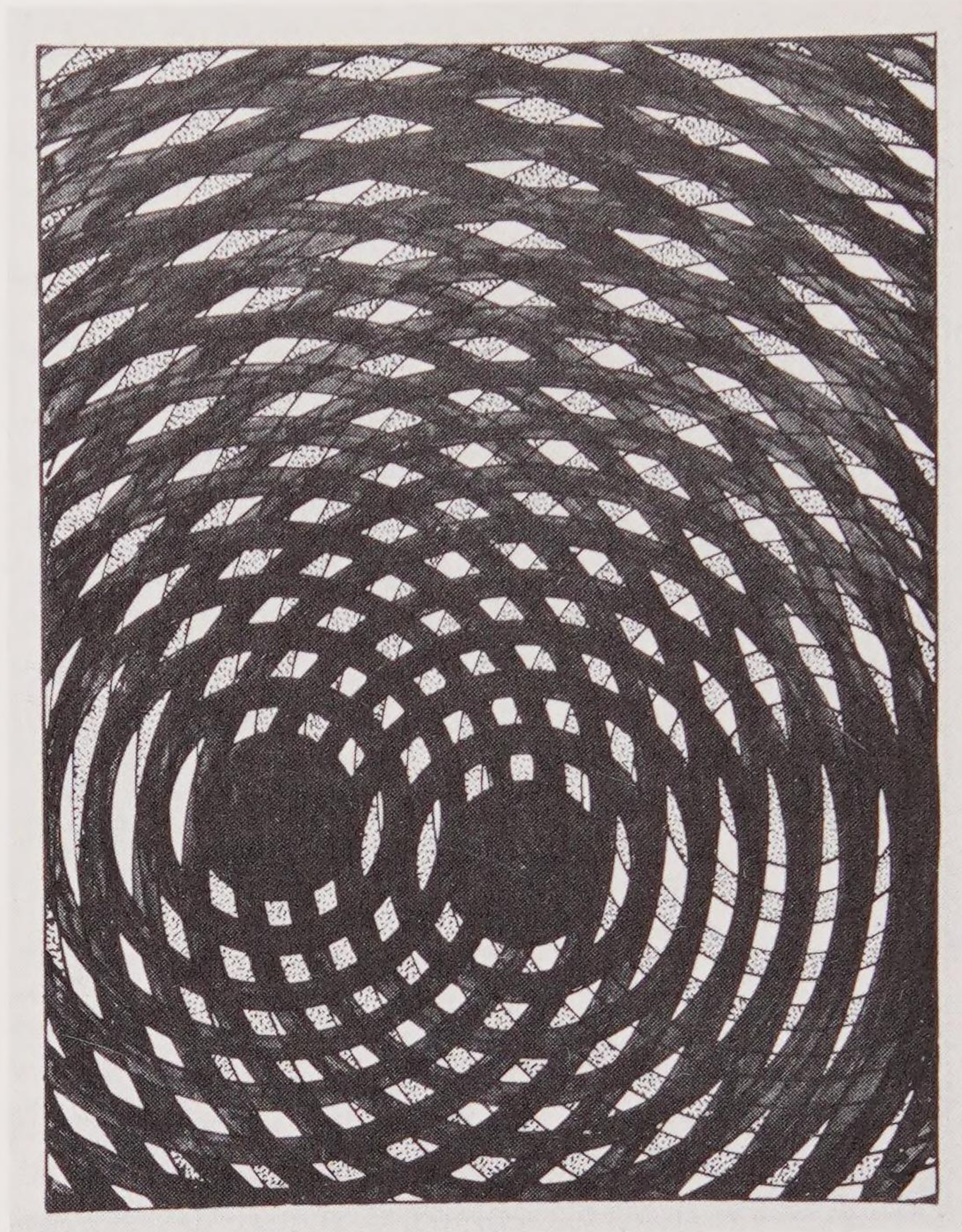


**Figure 11** Repeating curved lines in tunnel arrangement reported during marihuana-induced imagery sessions. Drawing by Sheridan, pen and ink.

see color section) and generally located in the periphery of these images (Fig. 14). Complex imagery was often duplicated and repeated, not infrequently involving symmetrical geometric arrays (Fig. 15).

Initially subjects reported that form imagery was like a slide show or movie located about two feet in front of their eyes. As the high-dosage hallucinogen sessions progressed, subjects frequently claimed that they became part of the imagery itself (Fig. 16), and reporting for all but the trained subjects was periodically suppressed. It was at these times that subjects stopped using similes in their imagery reports and started reporting that images were, in point of fact, really what they appeared to be. This is undoubtedly related to McKellar's (1957) finding that subjects in mescaline and nitrous oxide experiences intermittently lose insight into the difference between literal and analogous meanings. Thus normal undrugged individuals might describe an experience in terms of the similes "like," "as if," or "it is as though," but mescaline-treated subjects describe experiences as "it is so." McKellar describes this "*feeling into experience*" as a type of exaggerated empathy with thoughts and hallucinations, when the complex imagery almost totally replaced the simple geometric forms. The content of this imagery primarily included recognizable landscapes, scenes, people, and objects subjects could identify as memory images, but often presented in unique combinations and arrangements. Our subjects' best estimate is that at the peak of the drug experience such imagery was changing at the rate of 10 images per second,



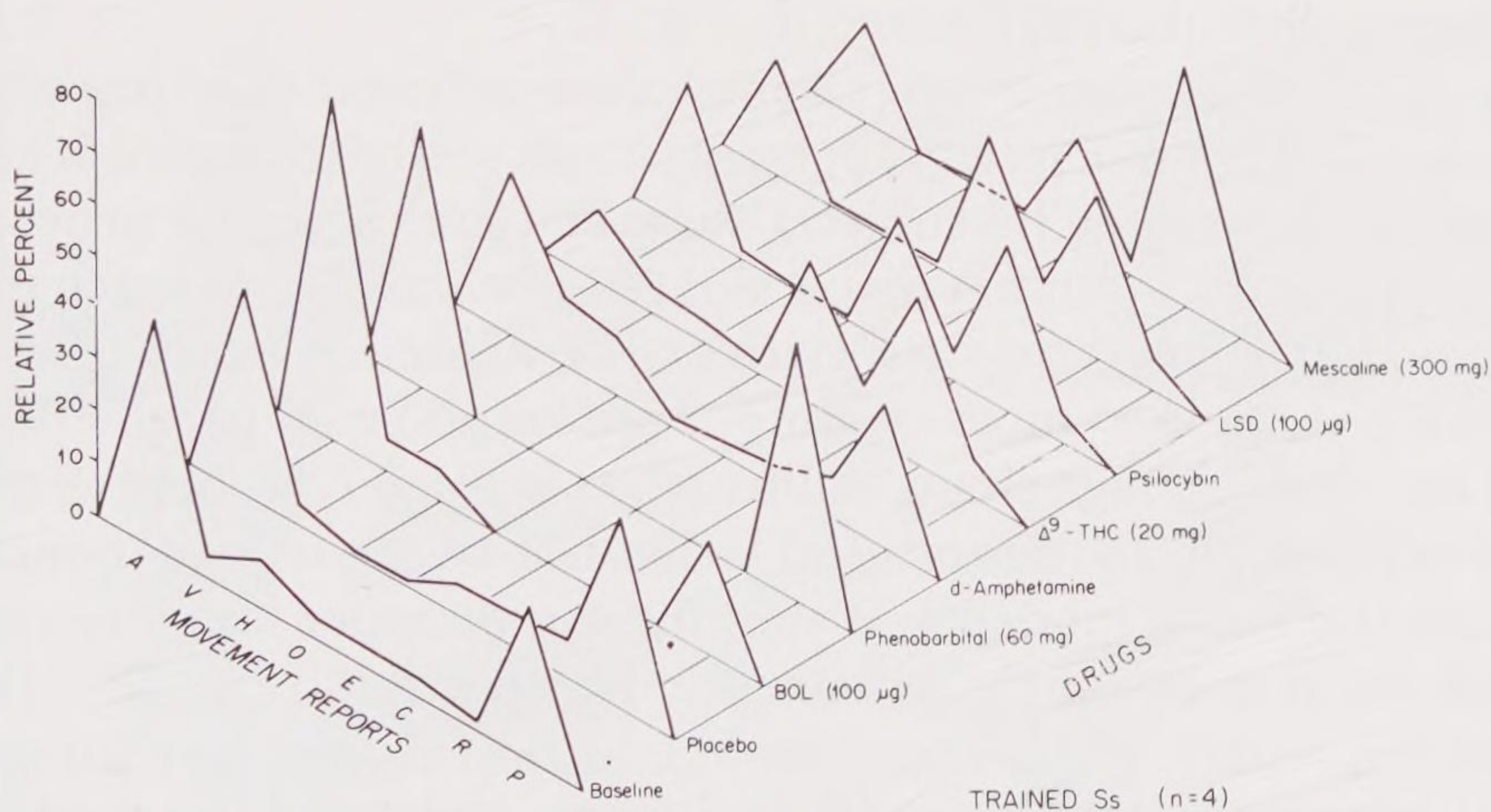
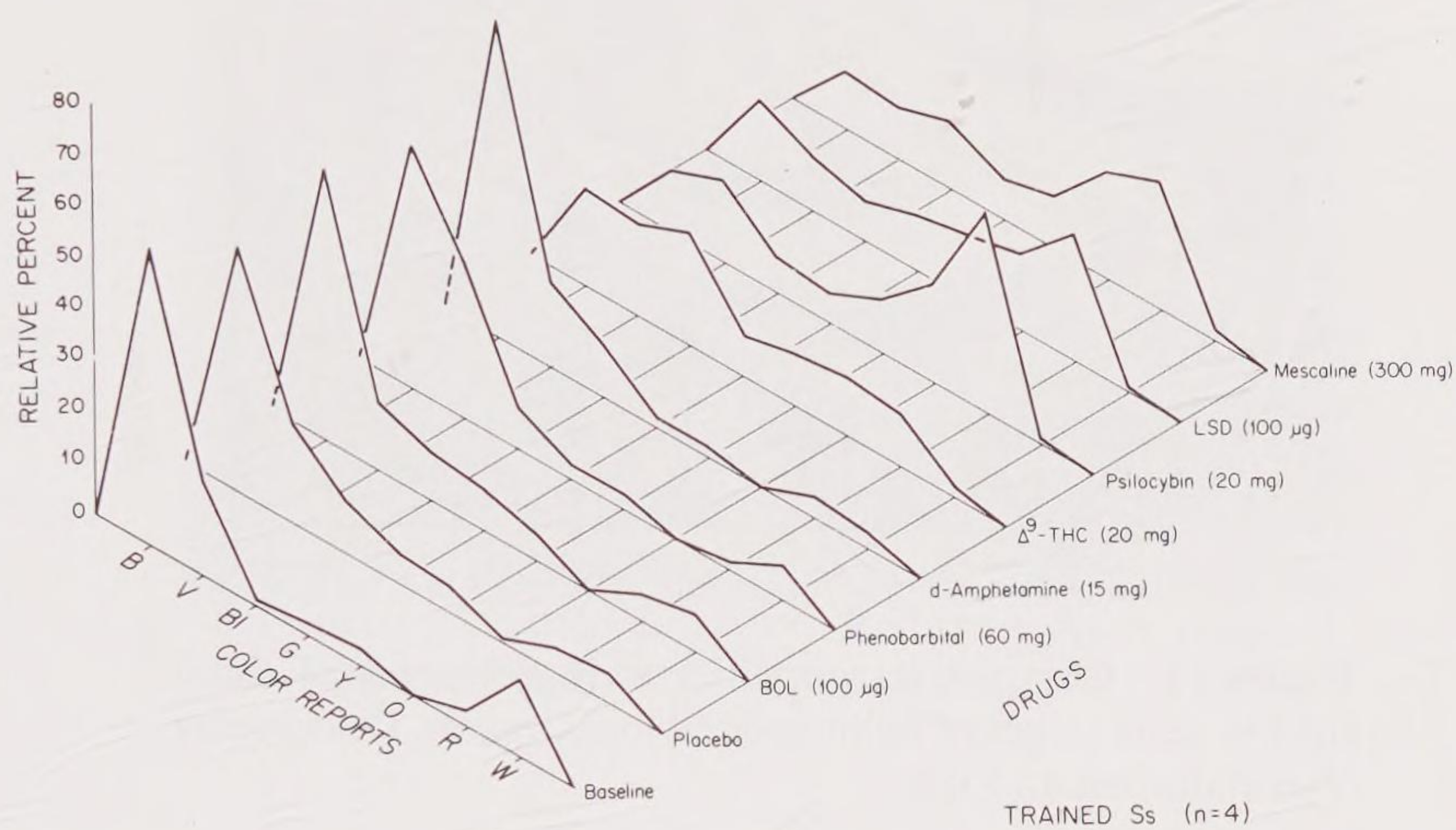
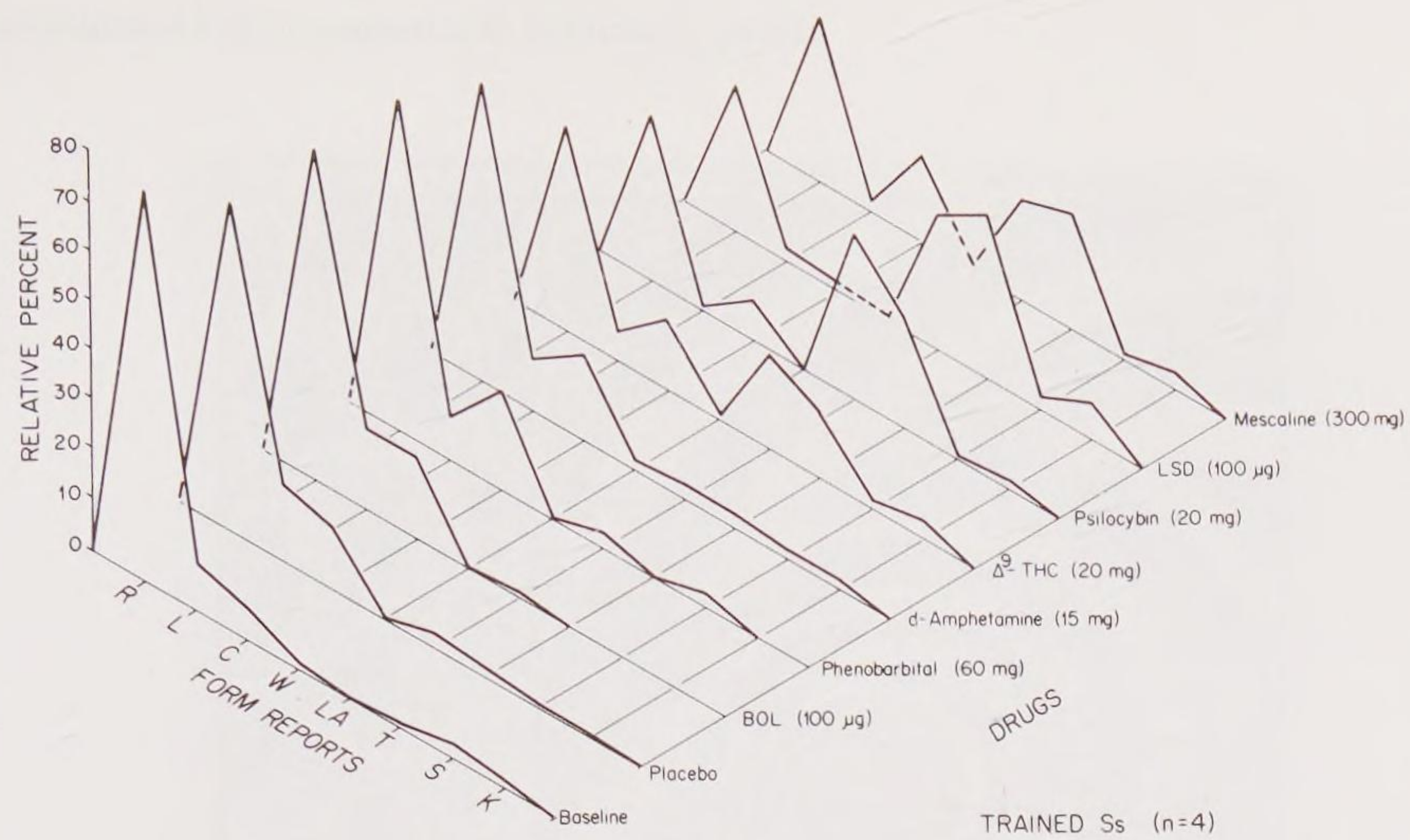


**Figure 12** Mean percent distribution of form, color, and movement reports for trained subjects in each six-hour high-dose drug condition. Form reports: R = random, L = line, C = curve, W = web, LA = lattice, T = tunnel, S = spiral, K = kaleidoscope. Color reports: B = black, V = violet, Bl = blue, G = green, Y = yellow, O = orange, R = red, W = white. Movement reports: A = aimless, V = vertical, H = horizontal, O = oblique, E = explosive, C = concentric, R = rotational, P = pulsating.





**Figure 14** Complex imagery located in periphery of visual field in early stages of hallucinogen intoxication. Drawing by Sheridan, pen and ink.

although they were not trained for making such judgments. One such sequence of complex imagery changes, illustrating how one image is associated with and influenced by another, is represented in Fig. 17.

McKellar (1957) describes a type of mescaline-induced thinking wherein the ability to inhibit and control irrelevant associations seems to diminish as the drug effect emerges. When one of his subjects was asked to explain the proverb "Those who live in glass houses shouldn't throw stones," she was able to reach the parable of the mote and beam by a purely associative chain of ideas: "glass house → glass → crystal → palace → castle → moat → mote → mote and beam parable" (p. 100). In the types of associative image changes illustrated in Fig. 17, we believe the subjects were simply experiencing drug-induced facilitation of this type of mental imagery projected into the visual modality. Typically, the memory imagery reported by subjects took on one of four characteristic perspectives (Fig. 18). During the outdoor sessions, there was a significant reduction in memory imagery and a concomitant increase in reports of birds, planes, trees, and other objects, often triggered by auditory and tactile cues in the outdoor garden setting. The latter finding is similar to Marinesco's (1933) report that mescaline-induced hallucinations were easily influenced by voice, sound, music, and smell. In one subject, for example, music induced moving visions of arabesques and murals spiraling about, while the smell of alcohol brought on images of a countryside. Also similar is



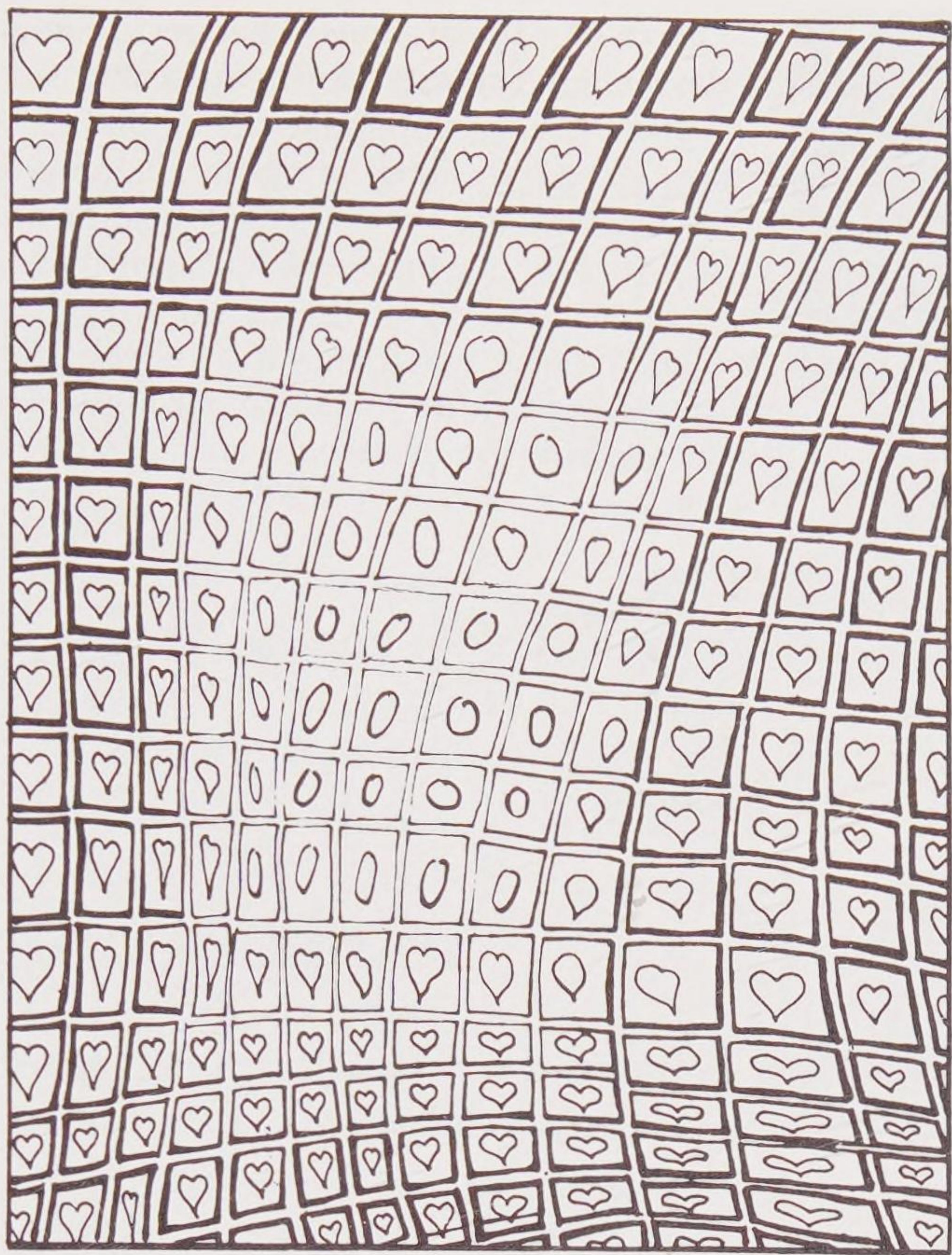


**Figure 15** Multiplication of complex imagery involving symmetrical lattice imagery. Redrawn from original subject's drawing by Sheridan, pen and ink.

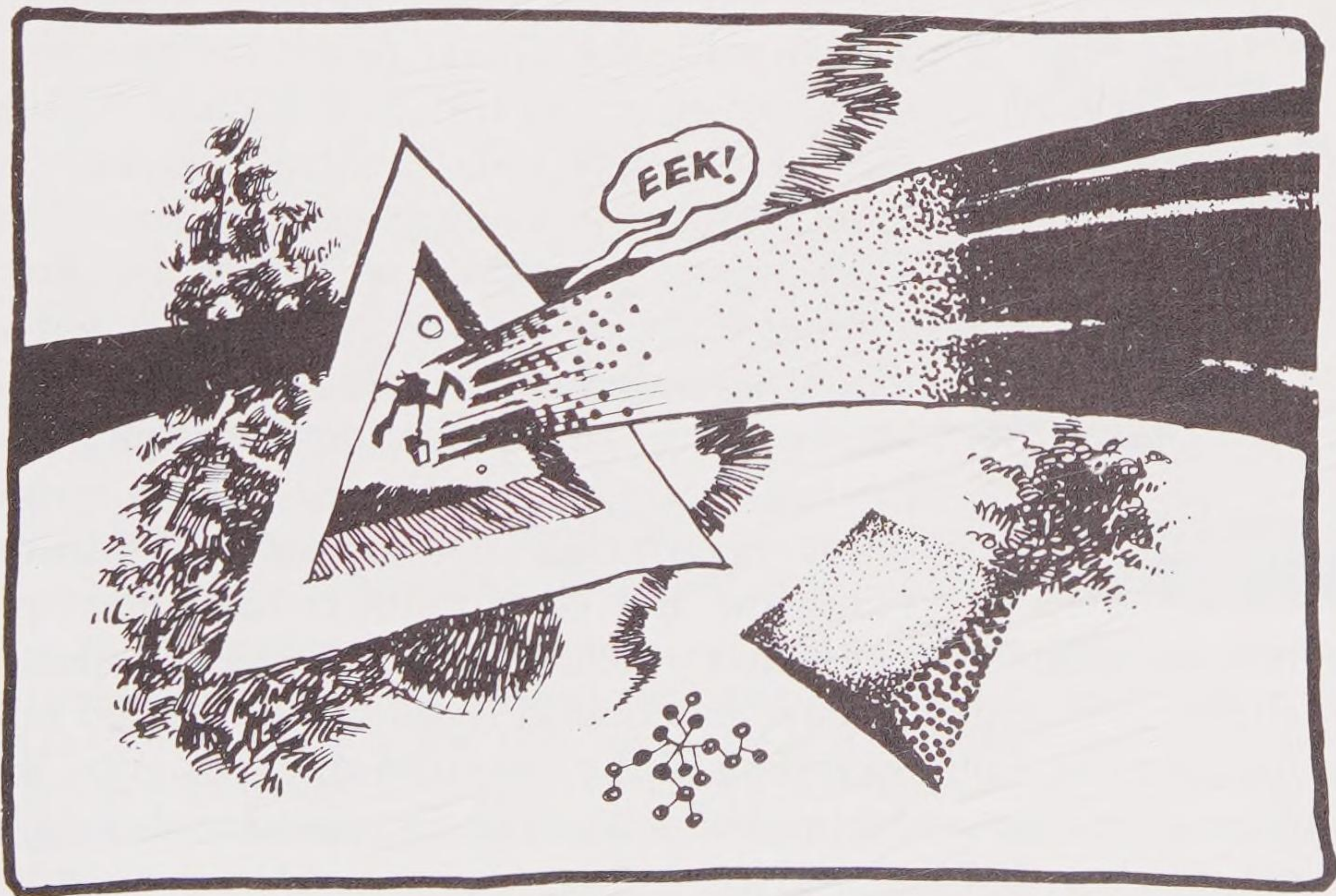


**Figure 16** Illustration of subject becoming part of visual imagery in psilocybin session. From *Mother's Oats, No. 1*, by Dave Sheridan, pen and ink. Reprinted with permission of the artist.



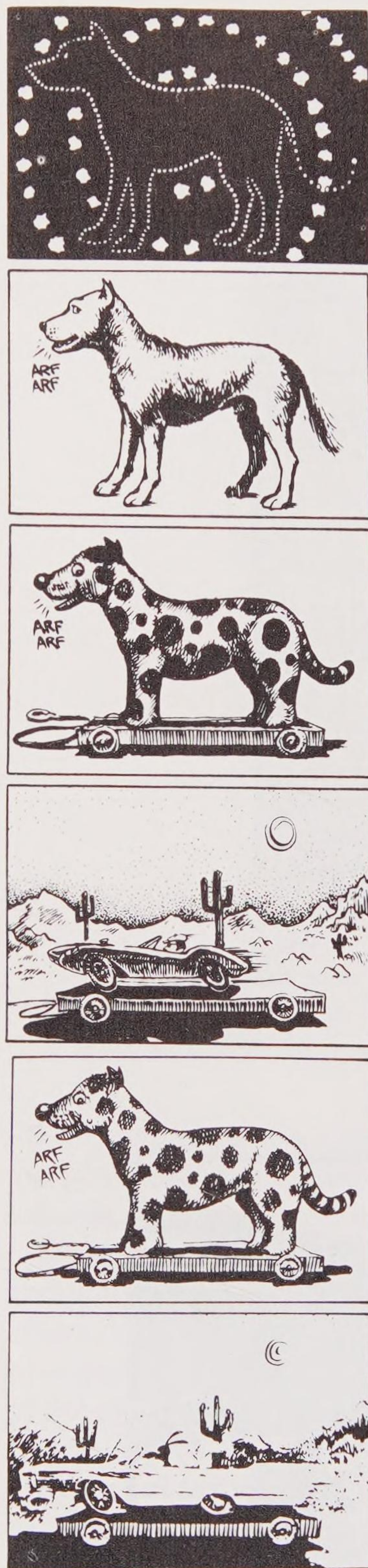


**Figure 17** Illustration of changes in complex imagery. Sequence shown here reported during mescaline session (200 mg). Subject reported: "I see pulsating stars outlining the shape of a dog overlaying a spiral-tunnel of lights, changing to a real dog which is barking with the words 'Arf, arf' coming out of his mouth, changing into a toy dog on wheels changing into a sports car on the same wheeled platform in the desert with the sun high in the sky, changing back into the toy dog still barking, changing back to the sports car with the Road-Runner and another cartoon character driving in the same desert scene." Drawing by Sheridan, pen and ink.

Singer's (1966) finding that extraneous stimuli can influence imagery, as in the case of the sound of feet running leading to the visual image of a child running.

### FLASHBACK IMAGERY

A flashback is usually defined as the return of part of the drug experience after the acute effects of the drug have worn off. Such flashbacks occur months or even years after the initial experience (Irwin, 1970), and the major symptoms experienced as flashbacks include depersonalization, perceptual distortion, and visual hallucinations (Stern and Robbins, 1969). Horowitz (1970) reviewed the phenomenology of flashback visual imagery and found the content to be primarily composed of complex images of people, places, or objects. The complex imagery is often idiosyncratic but similar to the imagery seen under the acute effects of the drug (Cohen, 1970). Examples of patient's LSD flashbacks include skulls of familiar people moving around the room, motion on a TV screen when the set is off, and frightening animals crawling around the room (Cohen, 1970). The mechanism of action of these flashbacks is unknown, although explanations based on a breakdown in the filtering of irrelevant stimuli entering the brain (Freedman, 1970) or cerebral seizure activity (Thurlow and Girvin, 1971) have been proposed.

Perhaps the most salient theory is that which views flashbacks as a special case of state-dependent learning whereby "statebound recall can be evoked not only by imagery, melodies, and other symbols of the *content* of an experience, but also by simply inducing that particular level of arousal which prevailed during the initial experience" (Fischer, 1971b, p. 32).

In a study of flashbacks following ketamine anesthesia (Siegel, Lebowitz, and Jarvik, unpublished data), six surgical patients were followed for 18 months after



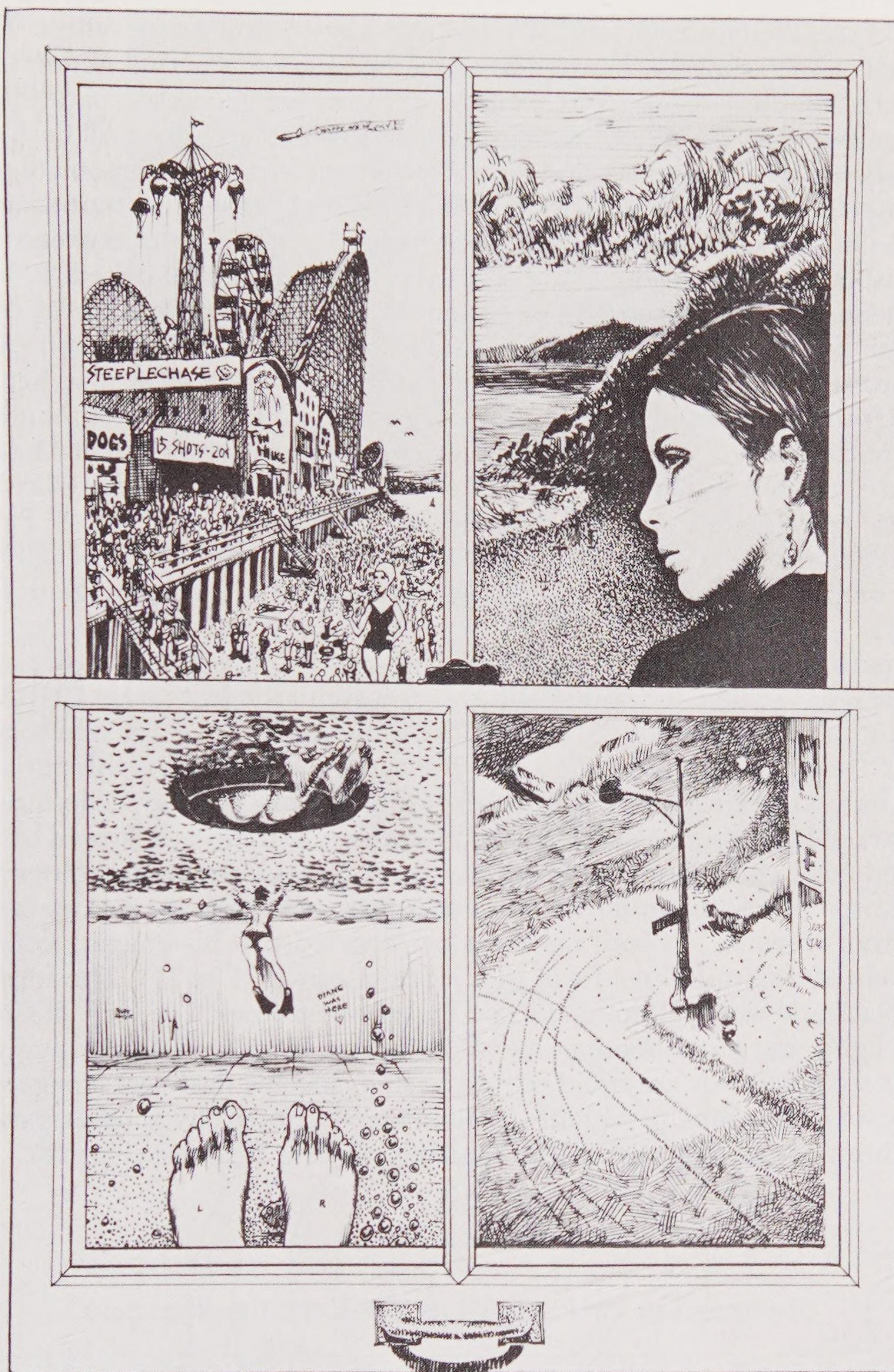


**Figure 18** Characteristic perspectives of memory imagery reported during hallucinogen sessions. Upper left: distant scene marked by abundant detail, often recognized as childhood event. Upper right: distant scene of landscape marked by detailed and recognizable image in foreground, often accompanied by emotional reports. Lower left: scene viewed as if subject were under water, looking up toward and through the surface. Lower right: aerial perspective, often accompanied by sensations of floating and flying. Drawing by Sheridan, pen and ink.



ketamine treatment (1–2 mg/kg, i.v.). Table 3 shows the total number of visual flashbacks reported for each patient in blocks of days following treatment. There was a total of 74 flashbacks reported by all patients over this period of time; 65 of these were complex images, and 9 (12%) were simple geometric patterns and colors composed of lattices, tunnels, and repeating lines and dots. All flashbacks were observed with open eyes, and most were characterized by immobility of the patient, as well as anxiety. Flashbacks lasted between a fraction of a second and five minutes. One patient required psychotherapy for a persistent anxiety reaction to these flashbacks. The vividness and clarity of this ketamine-induced flashback phenomenon was best illustrated by patient M.R.’s second flashback during the first week following treatment. The patient had a true hallucination of her physicians standing around her bed. Her surgeon advised her to take her bandages off, and the patient acted on this “suggestion” and removed her bandages, which contributed to the need of further corrective surgery. Patient A.M. reported the greatest number of flashbacks, which consisted primarily of either a geometric spiral pattern or one of three complex scenes as shown in Fig. 19. Taken together, these reported flashbacks support the view that flashbacks are largely composed of complex visual imagery with few if any hallucinogenic form-constants.

One particular case of LSD flashbacks, however, represents exclusive spiral-tunnel imagery. Patient R.S. entered the Neuropsychiatric Institute at UCLA with complaints about persistent LSD flashbacks. This patient reported a history of a dozen LSD experiences, but none within the last five years. During this period the patient was experiencing approximately two flashbacks per day. The incidents were marked by eyes-open visual imagery for about 15 minutes followed by acute panic and fear, which sometimes persisted for several hours. During observation in the hospital R.S. experienced two flashbacks while being tested in a dark, soundproof chamber. In both instances he reported that his imagery consisted exclusively of a spiral tunnel form with a bright center (Fig. 20). The form was always black and white, although he said that at other times “I’ve seen all kinds of colored lights and lines shooting out of it [the tunnel] at me.” Interestingly, this patient’s diagnosis was paranoid schizophrenic, and his flashback imagery was virtually identical to the persistent visual imagery reported by another paranoid schizophrenic studied at the UCLA Neuropsychiatric Institute (Fig. 21).

TABLE 3. DISTRIBUTION OF FLASHBACKS FOR KETAMINE PATIENTS

| Patients | Blocks of Days |      |       |       |       |       |        |         |         |
|----------|----------------|------|-------|-------|-------|-------|--------|---------|---------|
|          | 0–7            | 8–14 | 15–21 | 22–28 | 29–60 | 61–90 | 91–180 | 181–360 | 361–450 |
| M.R.     | 8              | 3    | 0     | 0     | 3     | 1     | 0      | 1       | 0       |
| A.M.     | 5              | 3    | 4     | 1     | 8     | 4     | 0      | 5       | 2       |
| I.D.     | 2              | 0    | 1     | 0     | 0     | 0     | 0      | 0       | 0       |
| E.G.     | 2              | 1    | 0     | 0     | 3     | 1     | 0      | 0       | 0       |
| G.G.     | 6              | 0    | 0     | 0     | 2     | 0     | 0      | 0       | 0       |
| P.L.     | 7              | 0    | 1     | 0     | 0     | 0     | 0      | 0       | 0       |



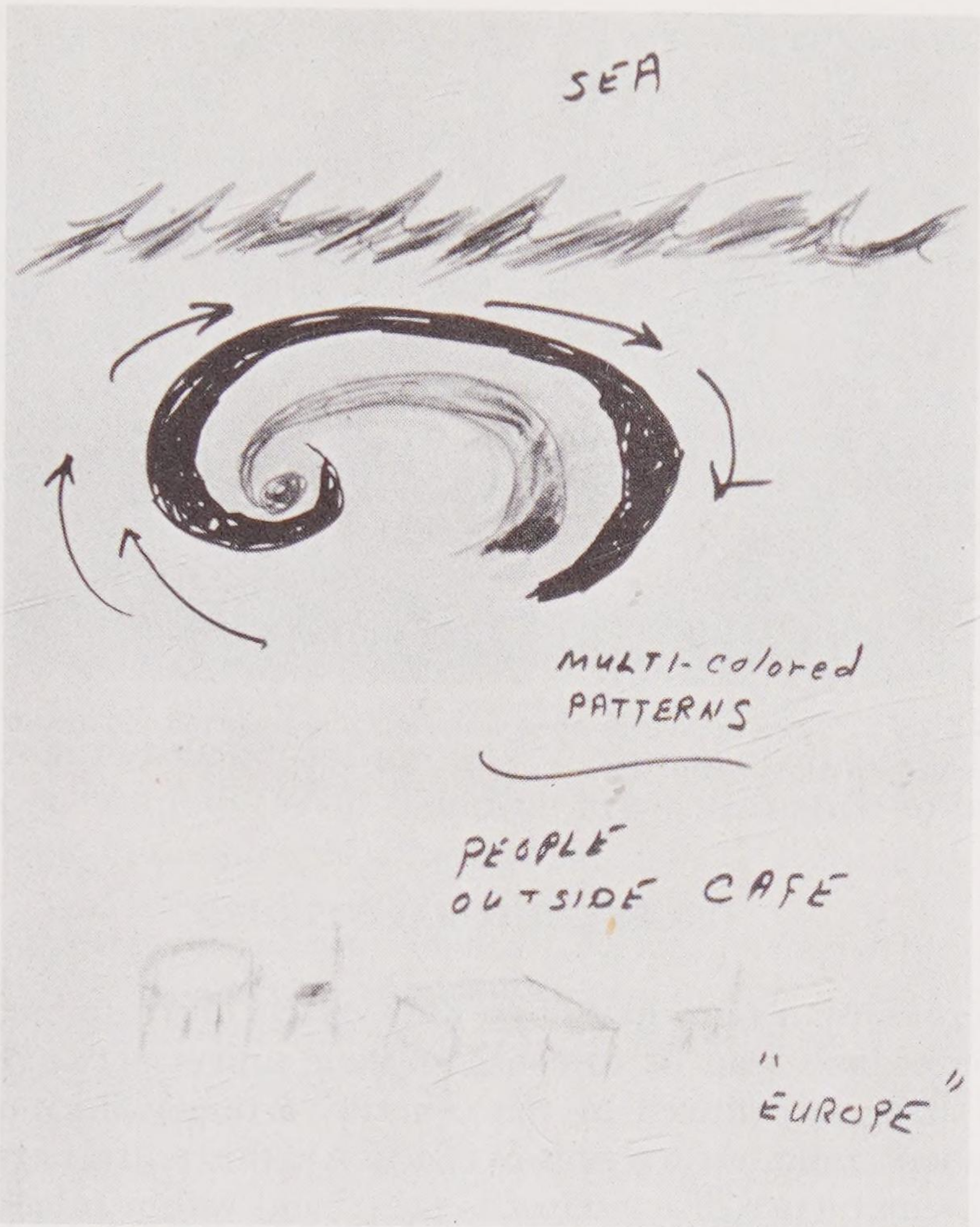


**Figure 19** Three types of ketamine-induced flashback images reported and drawn by patient A.M.

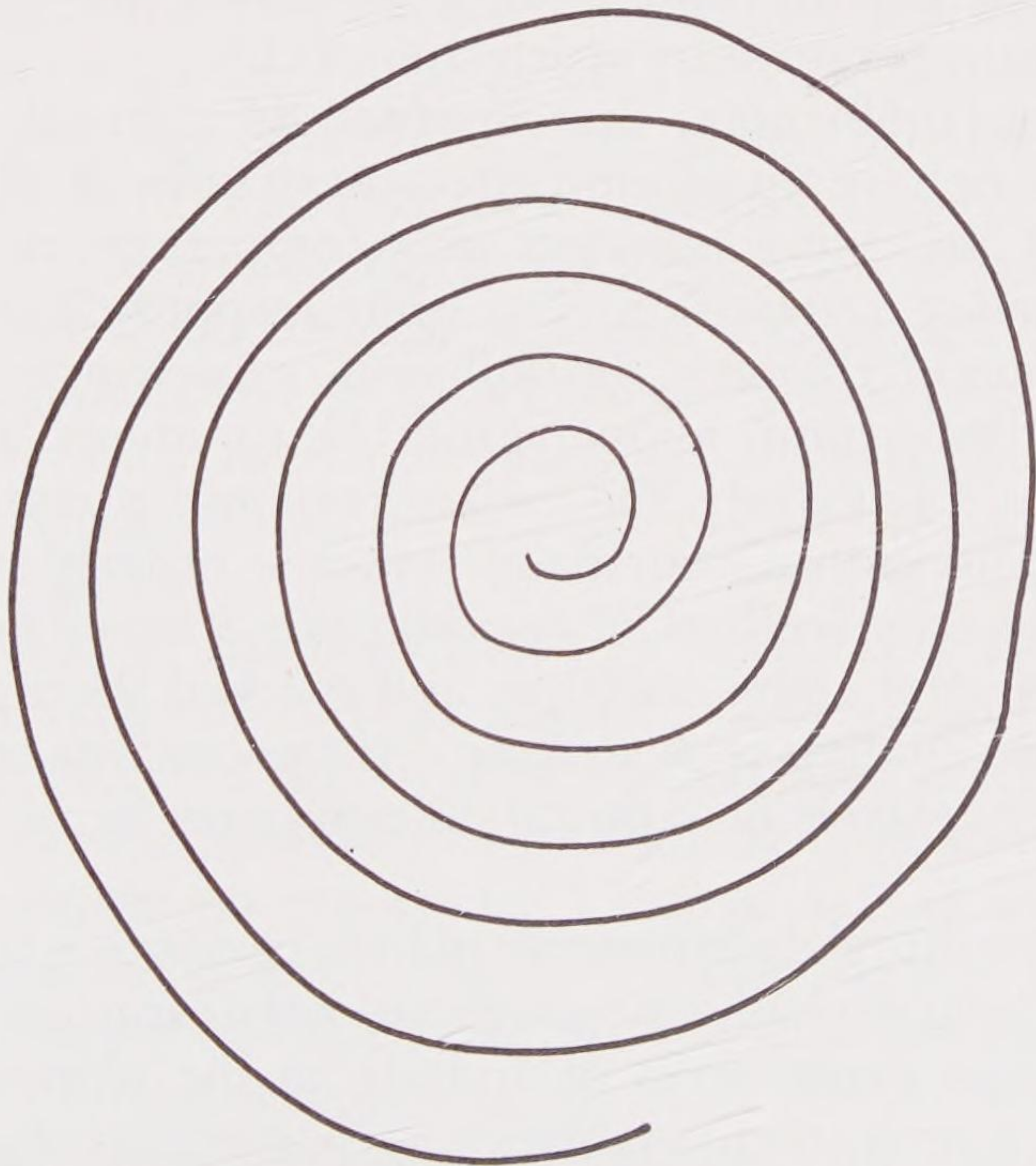


**Figure 20** Spiral-tunnel LSD-induced flashback imagery reported and drawn by patient R.S.



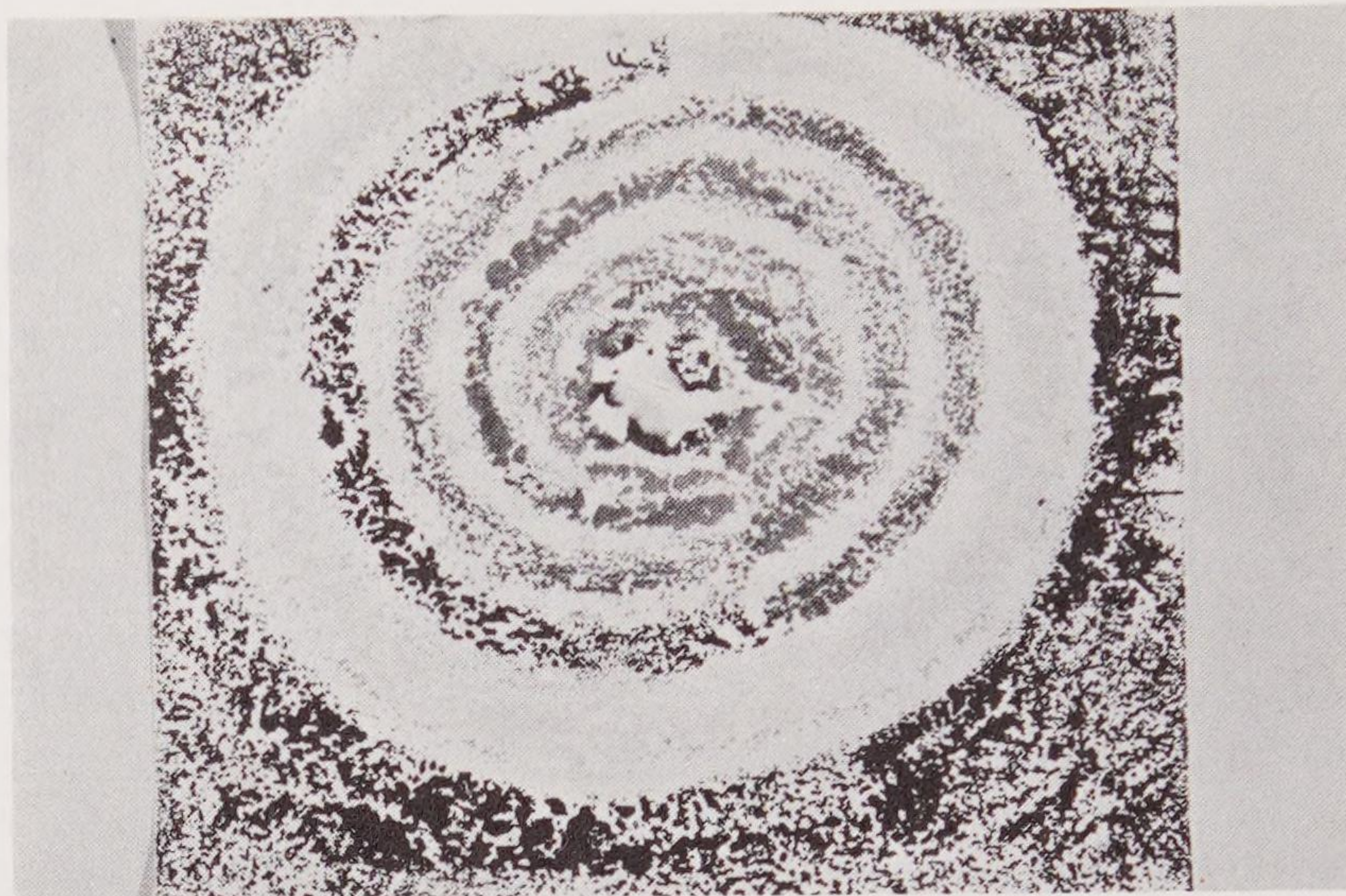


**Figure 21** Persistent eyes-open visual imagery reported and drawn by schizophrenic patient.

### CROSS-CULTURAL STUDIES

Visual imagery constants produced by a wide variety of treatments and in a wide variety of individuals lead us to consider their universality. The remarkable similarity of imagery induced by the centrally acting hallucinogens prompts speculation about common mechanisms of action in the central nervous system. In addition, the emergence of constants between and within subjects is strikingly similar to the construct of primordial images or archetypal forms, such as the mandala, which C. G. Jung (1969) claimed as part of man's collective unconscious. However, no matter how imperialistic we are in our theoretical desires, Freedman (1971) cautions that psychotropic drug experiences are very plastic and are formed by the cultural context in which they occur.

Indeed, Wallace (1959) notes that internalized cultural definitions of hallucinatory experience have a profound effect on an individual's responses, and he points out several prevailing contrasts in a comparison of white and Indian responses to mescaline intoxication. The white response is characterized by extremely variable mood changes, disinhibition, unwelcome feelings of depersonalization and dissociation, idiosyncratic hallucinations, and no permanent behavioral changes. Conversely, the Indian response is marked by a relatively stable mood, religious enthusiasm, maintenance of orderly and socially appropriate behavior, welcome feelings of contact with a new reality, hallucinations strongly patterned after some doctrine, and marked therapeutic benefits and behavioral changes. Finding such striking differences between the two peoples, Wallace argues for controls on cultural determinants in any research with hallucinogens.

The presence of cultural determinants of hallucinations is further illustrated by reactions to the aboriginal hallucinogen *Banisteriopsis* spp., also known as yagé or ayahuasca. The yagé experiences of Indians in the tropical forests of South America manifest several common themes, such as visions of jaguars, snakes, and other local predators, distant "cities," and recent crimes in the area (Harner, 1973). For example, consider the following account of ayahuasca visions:



Color visions, indefinite in form, began to evolve into immense vistas of enchanting beauty. . . . There was a tawny puma, several varieties of the smaller spotted ocelot, then a giant rosetta-spotted jaguar. . . . From a memory recess in my brain there emerged with the stimulation of the cats an experience from my past. On a trip to the Rio Putumayo a year before coming to the Jurua to cut *caucho*, I had come face to face on a forest path with a rare black jaguar. It had been a terrifying experience, but . . . we had gone our separate ways without violence. . . . This mighty animal now intruded on our visions and a shudder passed through us all. . . . Other animals, snakes, birds passed in review, each with some significant characteristic important to the Huni Kui [the tribe] in dominating the forest. . . . Then came scenes of combat with the hated enemy, the Guacamayos. . . . Scenes in the new village, where we now lived, gradually brought the visions to an end (Cordova-Rios and Lamb, 1971, pp. 157–158).

An example of such a rosetta-spotted jaguar, often reported in these visions, is provided in Fig. 22 (see color section). Nonetheless, despite the intrusion of such environmental stimuli into the visual imagery of yagé hallucinations, an equally common theme includes visions of geometric designs of bright colors and constantly changing shapes. Naranjo (1973) found tunnels and funnels to be particularly common elements in these yagé hallucinations:

The center can appear in the different visions as a source of motion or the region to which motion flows, a source of light or a perceiving eye, a geometric region such as a circular pond in the middle of Heaven or Hell, a being at the center of the earth, of the universe, the skull or inside the subject's body (p. 182).

The Tukano Indians in the Amazon region of Colombia frequently decorate their homes and pottery with large geometrical paintings of their yagé imagery (Reichel-Dolmatoff, 1972). Such motifs, derived from the initial stages of yagé intoxication, include curves, spirals, lattices, and the sun, as well as other forms remarkably similar to the Klüver constants. Interestingly, the Indians themselves claim that the hallucinations are a projection and that their order is fixed. Unsurprisingly, therefore, it has been hypothesized that the individual yagé user projects his cultural memory onto the waving screen of these geometric motifs (Reichel-Dolmatoff, 1972) and that these common themes "invite us to regard some shamanistic conceptions more as the expression of universal experiences than in terms of acculturation to local traditions" (Naranjo, 1973, p. 190). Indeed, Pokorny (1969) has compared the geometric designs on ornaments from several Neolithic artifacts with mescaline-induced form-constants and entoptic phenomena. He concluded that the similarity of all these reflects universal archetypes in man's history.

Common themes have also been noted in visual experiences associated with peyote (*Lophophora williamsii*) and San Pedro (*Trichocereus pachanoi*), both types of cacti that contain mescaline. Sharon (1972) reports that one Peruvian San Pedro vision consisted of "a whirlpool of red and yellow light spinning inward before my eyes and lightly printed on everything I looked at," as well as kaleidoscopic patterns and shapes. Lumholtz (1900, 1904) reported that Huichol Indians of Mexico represent the peyote cactus with traditional artistic designs consisting of concentric tunnel arrangements or spirals. Such designs may be based on the occurrence of hallucinogenic imagery constants for these people. Indeed, Schultes (1972) notes that peyote intoxication is often marked by "brilliantly colored visions in kaleidoscopic movement." Benzi (1969), however, argues that



such visions, no matter how abstract and geometric, are never dissociated from the cultural context. For example, symmetrical crystal forms seen at the peak of peyote intoxication are often impregnated with divinity and godlike forms, pinpoints of light are described as gods, and visions generally follow the tribal beliefs. Thus, even beyond certain universal visual images, "there are powerful cultural factors at work that influence, if they do not actually determine, both content and interpretation of the drug experience" (Furst, 1972, pp. 182–183). In this regard, it is of interest that the peyote visions of the Menomini Indians of Wisconsin reflect a common theme of salvation through baptismal conversion, perhaps indicating the acculturation of the imagery by North American Christian society (cf. Spindler, 1955).

In May 1972, one of us (R.K.S.) joined an expedition to study a group of Huichol Indians in the high Sierra Madre range of Mexico. Initially, 11 male Huichols, 23 to 78 years of age, were interviewed at the Centro Coordinador para el Desarrollo de la Region Huichol in Tepic, Nayarit. The respondents were probed about their peyote-induced hallucinations both with open eyes and closed eyes. Only one respondent denied any visual experiences; the rest offered remarkably similar accounts of their visions. The reports contained frequent references to snakes, deer, the sun, the moon, rainbows, the birth of the world, eagles, oxen, and other images having significance in the mythology and history of these people (cf. Lumholtz, 1898; Simoni-Abbat, 1963; Furst, 1969). In addition, there were numerous reports of geometric patterns, spirals, lines, tunnels, and lattices. One vision was described as "a big spiral and I saw the *Tatewari* [deified fire god] in the center and rushing out towards me. I saw mostly repeating squares, reds and blues, against the sky and everywhere I looked into the night." Most respondents had difficulty in describing the geometric visual imagery, but all agreed that such imagery was virtually identical to the symmetrical and repeating patterns used in Huichol embroidery and weaving. With the cooperation of the Museo Regional de Nayarit, we arranged to have several Indian artists depict their eyes-closed peyote imagery in the form of traditional yarn paintings; the results appear in Figs. 23 to 26 (see color section). Figure 26 depicts an eyes open true hallucination of a tree. The subject reported that this tree actually appeared on the mesa before him, but when he turned to move toward it, the image disappeared. The two groups of concentric circles or tunnel arrangements in figure 26 were not "seen" by the subject but used as a traditional symbol labeling peyote visions. This vision was reported at the peak of peyote intoxication.

Next, a small study was conducted on a group of four male Huichols during a ritual peyote ceremony conducted at our request in the remote village of Banco de Calitice. Over a period of several hours, each Indian ingested the equivalent of approximately 200 mg of mescaline in the form of a suspension of ground peyote buttons in water (0.002% mescaline in 100 g of peyote). The ceremony was conducted outdoors at sunset with about 60 people in attendance. Approximately four hours after ingestion, each subject gave a five-minute verbal report of eyes-closed visual imagery. Baseline reports of nondrug visual imagery were obtained five days later in a separate group of subjects. The reports were translated and analyzed according to the previously described method of scoring form, color, movement, and action constants. The four subjects made a total of 95 imagery reports during the peyote session, compared with 7 imagery reports



TABLE 4. DISTRIBUTION OF PEYOTE-INDUCED IMAGERY REPORTS FOR HUICHOL INDIAN SUBJECTS (N = 4)

| Form         |    | Color  |    | Movement   |    | Complex  |    |
|--------------|----|--------|----|------------|----|----------|----|
| Random       | 6  | Black  | 2  | Aimless    | 0  | Cattle   | 1  |
| Line         | 5  | Violet | 0  | Vertical   | 0  | Deer     | 4  |
| Curve        | 8  | Blue   | 9  | Horizontal | 3  | Eagle    | 3  |
| Web          | 0  | Green  | 0  | Oblique    | 0  | Mountain | 1  |
| Lattice      | 13 | Yellow | 3  | Explosive  | 11 | People   | 3  |
| Tunnel       | 15 | Orange | 1  | Concentric | 2  | Peyote   | 1  |
| Spiral       | 4  | Red    | 6  | Rotational | 2  | Snake    | 1  |
| Kaleidoscope | 7  | White  | 1  | Pulsating  | 3  | Stars    | 1  |
|              |    |        |    |            |    | Sun-god  | 10 |
|              |    |        |    |            |    | World    | 2  |
| Total        | 58 | Total  | 22 | Total      | 21 | Total    | 27 |

during the nondrug session. During the peyote session, 68 reports referred to simple forms, colors, and movement patterns, and 27 reports referred to complex scenes. From Table 4, which shows the distribution of these reports across the respective dimensions, it is clear that the predominant form is lattice-tunnel, the major colors are blue and red, and the primary movement is explosive motion toward the subject. In addition, the distribution of complex forms indicates a predominance of natural objects found in the Indians' immediate environment (e.g., the sun, deer, eagles).

PART III: A THEORY OF DRUG-INDUCED HALLUCINATIONS

The most apparent aspect of our findings on drug-induced hallucinations in man is the presence of form, color, and movement constants in the visual imagery. These constants are primarily lattice-tunnel forms, red colors, and exploding and rotational movements. The imagery appears to the observer as a movie or slide show located in front of his eyes and is characterized by a bright light in the center of the visual field. Complex imagery, consisting of recognizable people and objects, can overlay and sometimes replace these constants as the drug experience progresses from an initial geometric and fragmentary quality to more formed memory images. These complex images share the properties of the simple constants and are often presented in consistent symmetrical and repeating arrangements.

This fundamental phenomenology is illustrated in Fig. 27. Here we can see the basic lattice-tunnel form of the visual imagery. The tunnel appears to spiral toward the center of the visual field, where pulsating bright lights obscure any detail that might be present. The periphery of the tunnel seen in the foreground is clearer and more detailed than in the center. The peripheral lattices appear here



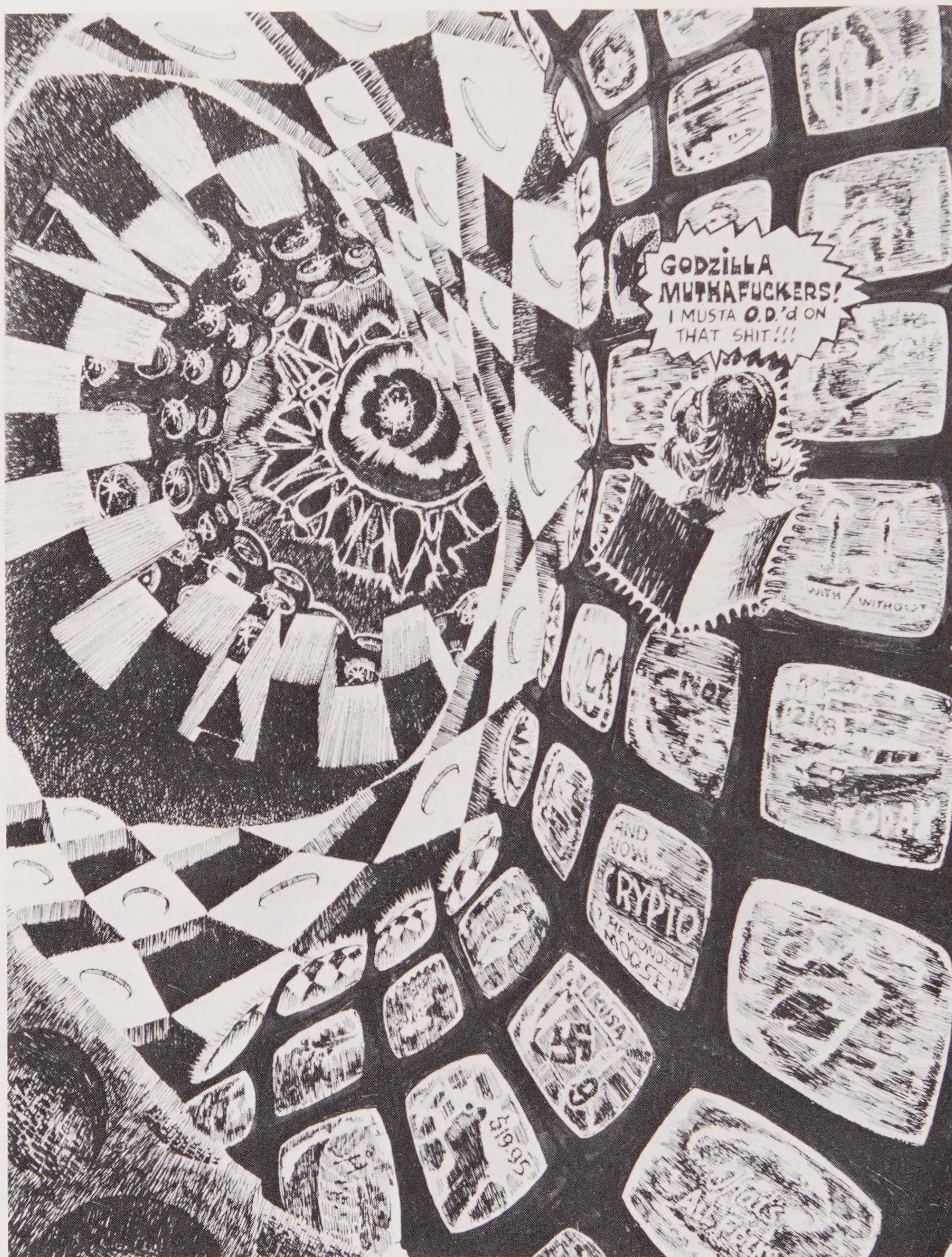


**Figure 27** Prototypic drug-induced visual imagery. From *Mother's Oats, No. 1*, Dave Sheridan, pen and ink. Reprinted with permission of the artist.



as small television sets containing distinctive complex images, which the subject reported as recognizable television scenes. He also reported that the imagery completely surrounded him, rotating about him on all sides. Subjects on high doses of hallucinogens typically report that the visual imagery surrounds them in this manner. For example, one subject in an LSD (100  $\mu$ g) session reported:

I see a visual image of the last movement of Berlioz's *Symphonie Fantastique*, which I listened to last night. All the goblins and witches are dancing around and teasing and tormenting me. The *idée fixe* is a cobra dancing around me, its tongue lashing out at my face, and now its body is encircling mine. Now Mickey Mouse and Donald Duck are in the circle shaking hands with me.

This particular account is uncannily similar to a *Datura stramonium* hallucination described by Boismont (1853): "[The subject] saw troops of men whirling [in] a circle before him, who endeavored to drag him into their vortex. All the characters in the ballet of *Gustavus*, in which he had been engaged during the evening, appeared to him making grimaces, and harassing him in every way" (p. 343). Boismont also describes a case of belladonna-induced hallucinations in which the subject found herself surrounded by small animals of various colors running on the ground.

The two basic phenomenological observations that emerge here are: (1) the form, color, and movement constants, and (2) the predominance of recognizable complex memory images. In the sections that follow, we consider explanations of these phenomena and attempt to develop a general theoretical model of hallucinations.

### FORM, COLOR, AND MOVEMENT CONSTANTS

**Similarity to Entoptic Phenomena.** Parish (1897) expressed one of the earliest opinions that visual hallucinations are the perception of entoptic events that arise from the visualization of certain structures within the eye through the appropriate arrangement of incident light. Since the work of Parish, numerous investigators have noted the similarity of drug-induced visual imagery to these entoptic phenomena. Marshall (1937) believed that mescaline may induce a "transient retroretinal illumination," enabling such phenomena to be observed:

The geometrical figures, in my opinion, are due to the compactness and small diameter and regular arrangement of the rods and cones and a light source behind, mainly pigment granules, producing diffraction-like figures (p. 293).

Marshall argued that the choriocapillary circulation was responsible for tapestry, ornamental, and floral designs; spirals; and for all the sinuous, circulatory, and multiplied movements. He believed that the luminous points in this circulation were responsible for fireballs, crystals, diamonds, and kaleidoscopic objects, whereas the retinal pigment and arrangement of rods and cones were responsible for the mosaics, honeycombs, and related lattice patterns. He even claimed that the cone or funnel distortion (tunnel form-constant) could be explained in terms of entoptic events:



The purely geometric forms of squares, hexagons and the like probably arise . . . from the smallness and regularity of cross sections of the rods and cones producing diffraction-like effects. The perspective effect [tunnel] arises partly from the foveal cones and enviroing rods being smaller and more closely arranged than those of the periphery, and in consequence the geometrical figures perceived are likely to be smaller in the centre than at the periphery; and it is enhanced by the luminous points or areas which may be present in the region of the fovea (p. 300).

Maclay and Guttman (1941) found examples of these entoptic phenomena in artists' drawings of their mescaline-induced hallucinations. These authors also noted the similarity of "elementary visual sensations" to elaborated complex hallucinations, which they suggested were simply projections of mental imagery. They concluded that the formal character of mescaline hallucinations is so similar to physiological and pathological phenomena that the former can be assumed to be physiological, whereas the contents of the complex hallucinations are determined by individual psychological experience. Zador (1930) referred to the elementary visual sensations as "primitive" imagery and labeled the complex imagery "scenic." Zador, like Maclay and Guttman, believed that both types of imagery originated from the same geometric patterns and were subject to the same controlling variables. Such a controlling variable could be entoptic phenomena. Indeed, the hypothesis has been advanced that hallucinogens like LSD may lower the threshold for perception of these events (Barber, 1970, 1971).

Adler (1959) described various types of entoptic phenomena; some are the result of normal structures within the eye, and others arise from imperfections such as opacities in the ocular media (cells with opaque nuclei, which can cast an umbra on the retina and produce a positive scotoma). In either case, entoptic phenomena are usually not seen because the subject does not attend to them, because they adapt out as "stabilized images," or because the illumination conditions are not appropriate (Adler, 1959; Hall et al., 1970). Indeed, some light is necessary for the observation of most entoptic phenomena, as described by Adler (e.g., superficial horizontal bands due to folds in corneal epithelium that change with eyelid motion; a longitudinal strip due to lacrimal fluid that adheres to the upper-lid margin, central moving bright spots surrounded by a dark ring due to droplets of tear fluid and mucus on the cornea; diffraction of light by radial fibers of the lens; a black lacework seen against a red background due to retinal blood vessels, which cast a shadow on rods and cones; and pulsating figures due to excursions of distended blood vessels on underlying receptor cells). Adler also suggests that small dancing spots seen entoptically may be caused by red blood cells passing through retinal capillaries. During the passage of these cells, sometimes called "floaters," the hemoglobin in the cells absorbs blue light and casts a shadow on the underlying rods and cones. It could be speculated that this phenomenon is related to the blue colors reported by subjects during the early stages of hallucinogenic intoxication, particularly with THC (Part II). These subjects did not report the colors in motion as they were in the supine position, where the loose cells could settle in an aqueous pool in the foveal crater, thus stopping all movement (White and Levatin, 1962). However, the area around the fovea, corresponding to the center of the visual field, does not contain retinal blood vessels and fails to show these entoptic phenomena. This could be related to the bright light and loss of central detail observed in drug-induced visual imagery.



Light is necessary for most entoptic phenomena, but it is not required for a type known as *eigengrau* or phosphenes. Eigengrau or phosphene phenomena occur in the dark where a normal subject does not see black but rather [a sensation of] grayness (Adler, 1959); they are characterized by neuronal discharge activity in the retina, lateral geniculate, and visual cortex (R. Jung, 1972). Phosphenes may also include spots, disks, concentric arcs or circles, and even checkerboard patterns. Rapid eye movement causes "flick phosphenes" or a sensation of motion in these patterns. These patterns and effects can also be induced by light pressure on the closed eyelid. Oster (1970), whose illustrations of phosphenes include examples of lattices and spiral tunnels, claims that hallucinogens also produce these phenomena. Since the phosphene phenomena are partly due to pressure on the retina (Ladd-Franklin, 1927), and LSD raises intraocular pressure (Holliday and Sigurdson, 1965), Oster's suggestion of hallucinogen-induced phosphenes could be related to such reactions. The finding, recently contested by Adams and Flom (1972), that marihuana reduces intraocular pressure (Hepler and Frank, 1971), but induces identical imagery phenomena (Part II), casts doubt on such a mechanism of action. Nonetheless, phosphenes may account for many other subjective visual phenomena ordinarily labeled hallucinations:

Phosphenes may account for the "illuminations," the visions or the experience of "seeing the light" reported by religious mystics meditating in the dark; they are the "prisoners' cinema" experienced by people in dark dungeons; they may well constitute the fact behind reports of phantoms and ghosts. . . . Phosphenes are a hazard to the long-haul truck driver peering for hours into a snowstorm. Airplane pilots often experience phosphenes, especially when they are flying alone at high altitudes, where the sky is cloudless and empty of the usual depth cues (Oster, 1970, p. 83).

As appealing as such entoptic events are for explaining drug-induced constants, since some light is required for their visualization, they play a minimal role in the determination of visual imagery constants as found in our experiments conducted in total darkness (Part II). The presence of some LSD- or marihuana-induced visual imagery in totally blind subjects (Krill et al., 1963; Kirtley, 1971), as well as non-drug-induced complex hallucinations in recently blinded subjects (Fitzgerald, 1971), would seem to support this notion. However, adequately controlled studies with blind subjects have not been conducted, and the latter point must be accepted with caution (cp. Rosenthal, 1964). Moreover, recent neurophysiological studies in cats have found that hallucinogens like LSD and DMT "mimic" the effect of light on the retina (Heiss et al., 1973) or on EEG tracings (Marczynski, 1972), and such drugs "might be interpreted by the brain as light and this may contribute to the origin of abnormal reactions within brain structures which are also influenced, leading to hallucinations" (Heiss et al., 1973, p. 457). Additionally, we question the exclusive role of entoptic phenomena here because they are not as symmetrical or as well-organized as the drug-induced constants.

Many investigators have suggested that retinal blood vessels and capillaries contribute to drug-induced form-constants such as spirals (e.g., Marshall, 1937; Klüver, 1942), but others (e.g., Wise et al., 1971) have shown that the pattern and structure of retinal vessels (Fig. 28) are simply not as regular and geometrical as drug-induced visual imagery. It remains possible, however, that such entoptic





**Figure 28** Retinal blood vessels. Drawing by Sheridan, pen and ink.

structures only provide the basic structural templates for the cognitive elaboration in higher centers to imagery constants (cf. Horowitz, 1972). Indeed, Barber (1970) reviews compelling evidence showing that phosphenelike phenomena may be induced at higher levels of the visual system than the retina itself.

**Similarity to Migraine Hallucinations.** Similar phosphenelike phenomena have been observed in migraine hallucinations (Maclay and Guttman 1941; Oster, 1970). For example, Maclay and Guttman found instances of mescaline-induced zigzag lines, similar to the fortification patterns of migraine hallucinations, moving from the center of the visual field to the periphery. Richards (1971) described these classic fortification “illusions,” which often precede or accompany the head pain:

It generally begins near the center of the visual field as a small, gray area with indefinite boundaries. . . . During the next few minutes the gray area slowly expands into a horseshoe, with bright zigzag lines appearing at the expanding outer edge. These lines are small at first and grow as the blind area expands and moves outward toward the periphery of the visual field (p. 89).

These patterns may show changes in color, line orientation, and in spacing between the lines. The arc may become a grid, and the colors may change from black and white to red, blue, and yellow. Often the basic patterns change into different geometric arrays. For example, one patient reported seeing “a bright red, central flickering spot composed of many smaller spots. The central scotoma quickly expands into concentric circles of multicolored spots that obscure whatever he looks at” (Hachinski et al., 1973, pp. 573–574). Migraine phenomena also include the development of fully formed hallucinations, including people and scenes, which often accompany these geometric displays. Distortions of body imagery (e.g., growing bigger or smaller) are also reported. Lewis Carroll wrote



about such personal migraine attacks in his diary, and it has been suggested that some of *Alice's Adventures in Wonderland* may have originated in his migraine hallucinations (Lippman, 1952).

Although the mechanism underlying the production of these phenomena remains uncertain, Hachinski et al. (1973) believe that it is unlikely to be based on entoptic events. Alternatively, these authors favor Lashley's (1941) and Richards's (1971) argument that migraine visual images provide information on the arrangement of cells in the visual cortex, which are probably excited by a spreading wave of cortical depression. For example, the regular geometric nature of migraine fortification patterns, similar to drug-induced patterns in that respect, may represent the electrical output of organized groups of cells in the visual cortex. Somjen (1972) notes that the visual cortex is organized as a mosaic of detectors of contrast, with each element representing a defined orientation relative to the visual horizon and functioning in the detection and recognition of all shapes. Excitation of these elements by a smooth electrical wave traveling across the cortex from one individual discrete element to the next could create both geometric designs and the consistent patterns of movement. Indeed, Richards (1971) argues that line detectors are probably organized in the cortex in lattice arrangements, and excitation of these detectors could account for lattice forms in migraine as well as in other phenomena. This discrete cortical organization might be expected to give rise to only straight-line figures. But all outlines with curved or straight edges can be subdivided into sets of straight lines, since the direction of a curve at any point is defined by the orientation of its tangent. Thus excitation of cortical line and edge detectors can produce circular as well as straight figures.

### COMPLEX MEMORY IMAGERY

**Brain Excitation.** Thus far we have seen that excitation of the central nervous system with hallucinogens (Part II), by photostimulation (Symthies, 1960), by electrical current (Knoll et al., 1962), or in migraine, results in remarkably similar visual imagery constants. Even direct electrical stimulation of man's visual cortex or temporal lobes produces moving and stationary colored lights, geometric forms, stars, and lines (Penfield, 1958; Knoll et al., 1962). Several investigators have suggested that the central nervous system excitation induced by hallucinogens may be directly related to hallucinations (e.g., Winters and Wallach, 1970). For example, Wikler (1954) examined the EEG records of 12 subjects given mescaline (700 mg) and found that 6 displayed intermittent desynchronization concomitant with their verbal reports of hallucinations.

Hebb (1968) proposed a theoretical model to explain how hallucinations may develop from this excitation:

In normal waking hours there is a constant modulating influence of sensory input upon cortical activities, helping both to excite cortical neurons and to determine the organization of their firing. When this influence is defective for any reason—pathological processes, or habituation resulting from monotony or “sensory deprivation”—there is still cortical activity. . . . The activity may be unorganized. . . . But when by chance the spontaneous cortical firing falls into a “meaningful” pattern—when the active neurons include enough of those constituting a cell assembly to make the assembly active and so excite other



assemblies in an organized pattern—S may find himself with bizarre thoughts or . . . with vivid detailed imagery (pp. 474–475).

This process can be initiated by treatment with hallucinogens, which would have the cortical disorganizing effect referred to by Hebb (Marrazzi, 1962). Indeed, Hernandez-Peon (1968) maintains that hallucinogens “act first by disinhibiting that part of the cortex which lies in the temporal lobes and corresponds to the recent memory system. Therefore, if that part of the cortex is removed (as in recent studies with chimpanzees), the drug cannot act, and thus there would be no hallucinations” (p. 190).

In the intact brain of man, the result of such excitation is the production of visual imagery. A number of investigators have described this phenomenon for various forms of excitation. Moreau (1845) wrote of the hashish-induced excitation of the brain which enabled thoughts and memories to be visualized. Timothy Leary and his co-workers (1964) claimed that hallucinogens like LSD enabled one to watch the contents and processes of the human mind. Lilly (1970b) described how imagery induced by sensory deprivation comes from “program storage” (memory) and internal body sources of excitation. The excitation causes visual displays to be projected onto a normally-blank screen in front of the eyes. The subject then

interprets the resultant filling of these perceptual spaces at first as if this excitation were coming from outside. In other words, the sources of the excitation are interpreted by the self as if coming from the real world. For certain kinds of persons and personalities this is a very disturbing experience in one sphere or another . . . (Lilly, 1970b, p. 29).

Penfield (1958, 1970) described excitation induced by cortical stimulation as memory “flashbacks” and “*experiential hallucinations*”:

These hallucinations are made up of elements from the individual's past experiences. They may seem to him so strange that he calls them dreams, but when they can be carefully analyzed it is evident that the hallucination is a shorter or longer sequence of past experience. The subject re-lives a period of the past although he is still aware of the present. Movement goes forward again as it did in that interval of time that has now been, by chance, revived and all of the elements of his previous consciousness seem to be there, sights, sounds, interpretations, emotions. The hallucination includes those things that were within the focus of his attention. The things he ignored then are missing now. Sometimes it would seem that even fancies reappear, as in the case of R.W., a little boy who saw “robbers with guns” such as he had seen pictured in his comic books (Penfield, 1958, p. 23).

**Memory Retrieval.** The notion of hallucinations consisting of complex memory imagery is neither a radical nor a new idea. It is not radical because it appeals to an intuitive sense of what is reasonable to infer. When one hallucinates something that is not there, the stimuli being perceived (i.e., the image) must come from some source. It is not reasonable for normal man to infer that such stimuli, when auditory, are “voices talking to me,” “radio waves from another planet,” or clairvoyant communications with a deceased loved one. Nor is it always reasonable to infer that the stimuli, when visual, are real (e.g., “that little green man is really there”) or self-contained in a recently administered drug (e.g., “God is in the LSD”). Rather, it is more reasonable to infer that such phenomena originate in stored information in the brain, that is, memories.



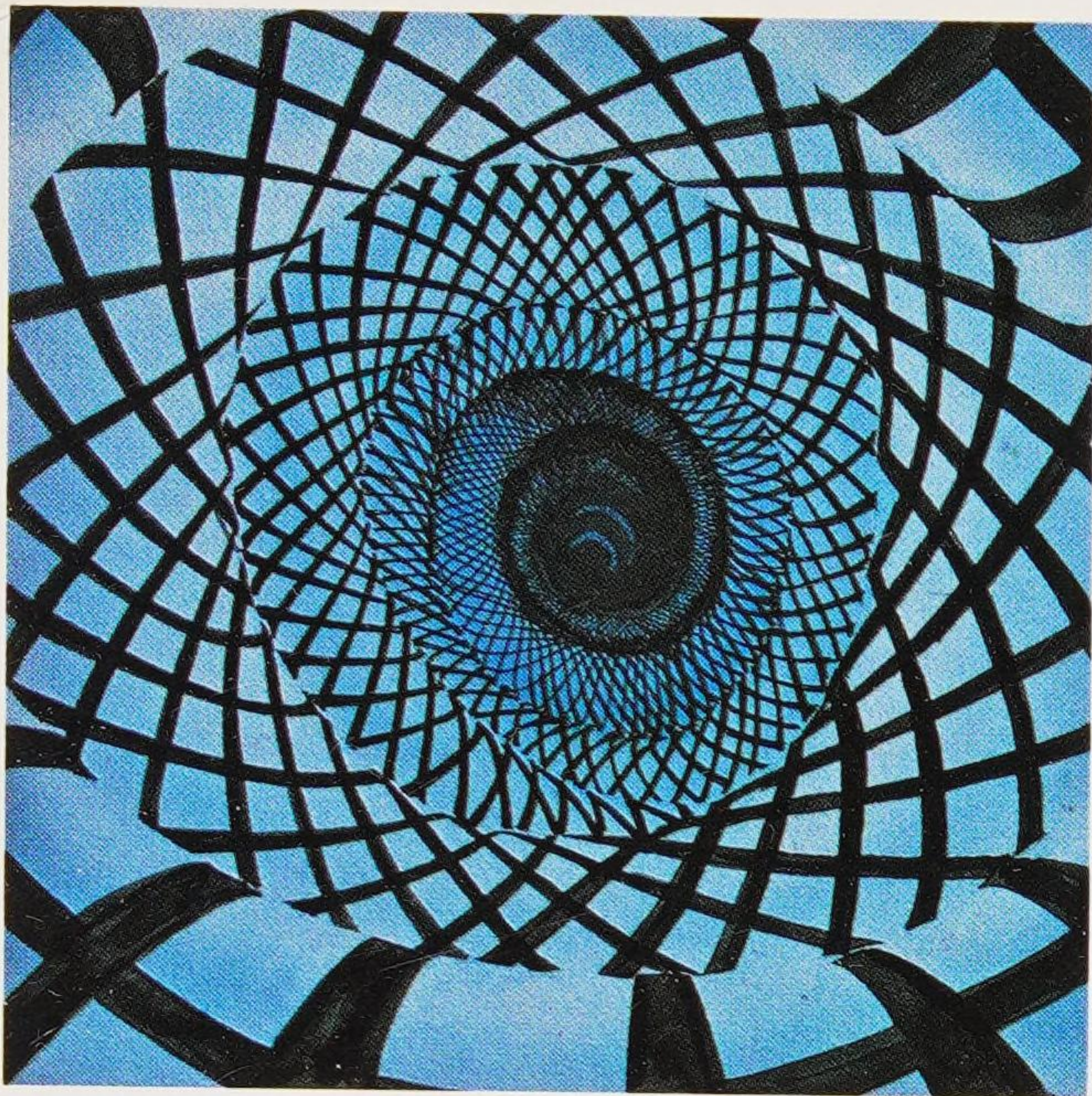


**Figure 6.** Blue lattice-tunnel reported in early stages of marihuana and THC intoxication. Synthesis of reports of 14 subjects. Drawing by Sheridan, pen and ink.

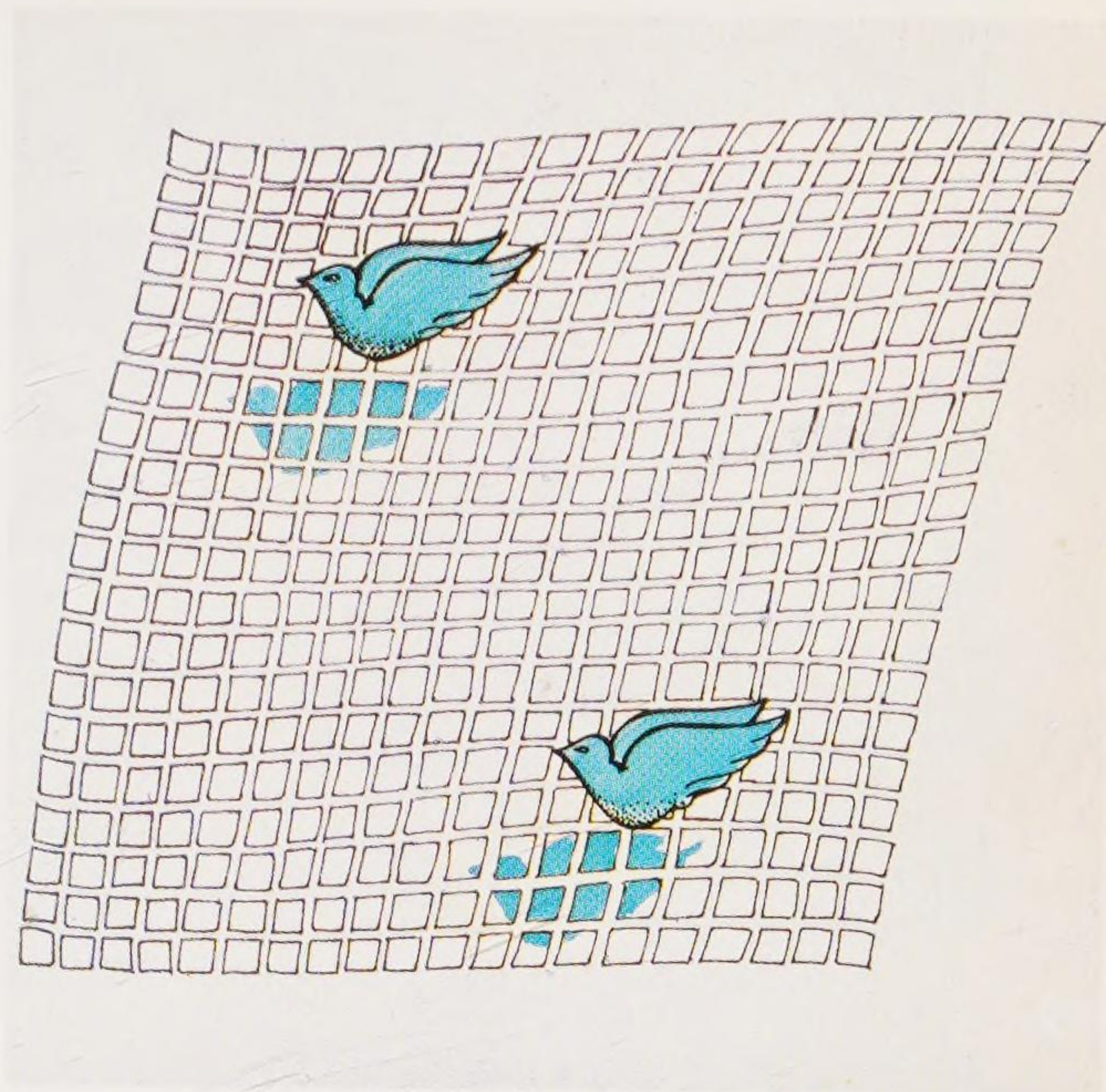


**Figure 13.** Illustration of complex imagery overlaying geometric lattice imagery in early stages of hallucinogen intoxication. Redrawn by Sheridan, pen and ink.

**Figure 22.** Depiction of an hallucinatory experience, by Yando, untitled, oil, 1971.







**Figure 23.** Huichol yarn painting depicting peyote-induced visual imagery of a peyote flower. Yarn on beeswax on wood.



**Figure 26.** Huichol yarn painting depicting eyes-open true hallucination of a tree. Yarn on beeswax on wood.

**Figure 24.** Huichol yarn painting depicting eyes-closed peyote-induced imagery. Subject reported bright light in center was the deified fire god. Deer heads were reported to be rotating over blue lattices. Vision during early stages of intoxication. Yarn on beeswax on wood. Painting by Martin de la Cruz.



**Figure 25.** Huichol yarn painting depicting eyes-closed peyote-induced imagery. The four red spiral tunnels were not actually "seen" by the subject but were used to indicate that this painting was a peyote vision. Interestingly, one of the traditional Huichol symbols for peyote is this spiral-tunnel design. Yarn on beeswax on wood. Painting by Martin de la Cruz.







**Plate I** Isaac Abrams, *Fly Leap*, oil, 1966. (By permission of Isaac Abrams, Stanley Krippner, and Grove Press.)

**Plate II** LSD-induced visual imagery (right and below). (By permission of Oscar Janiger.)

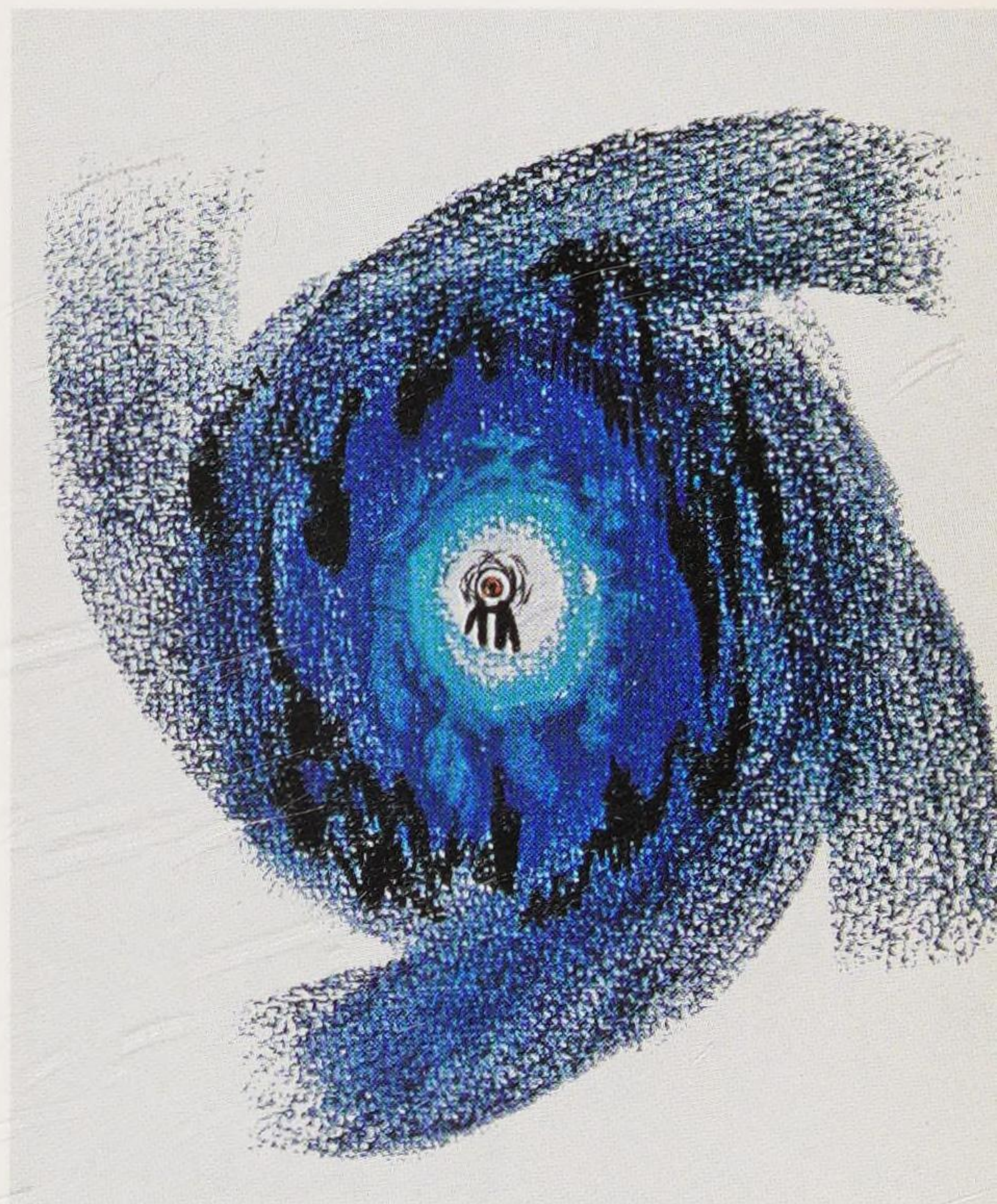
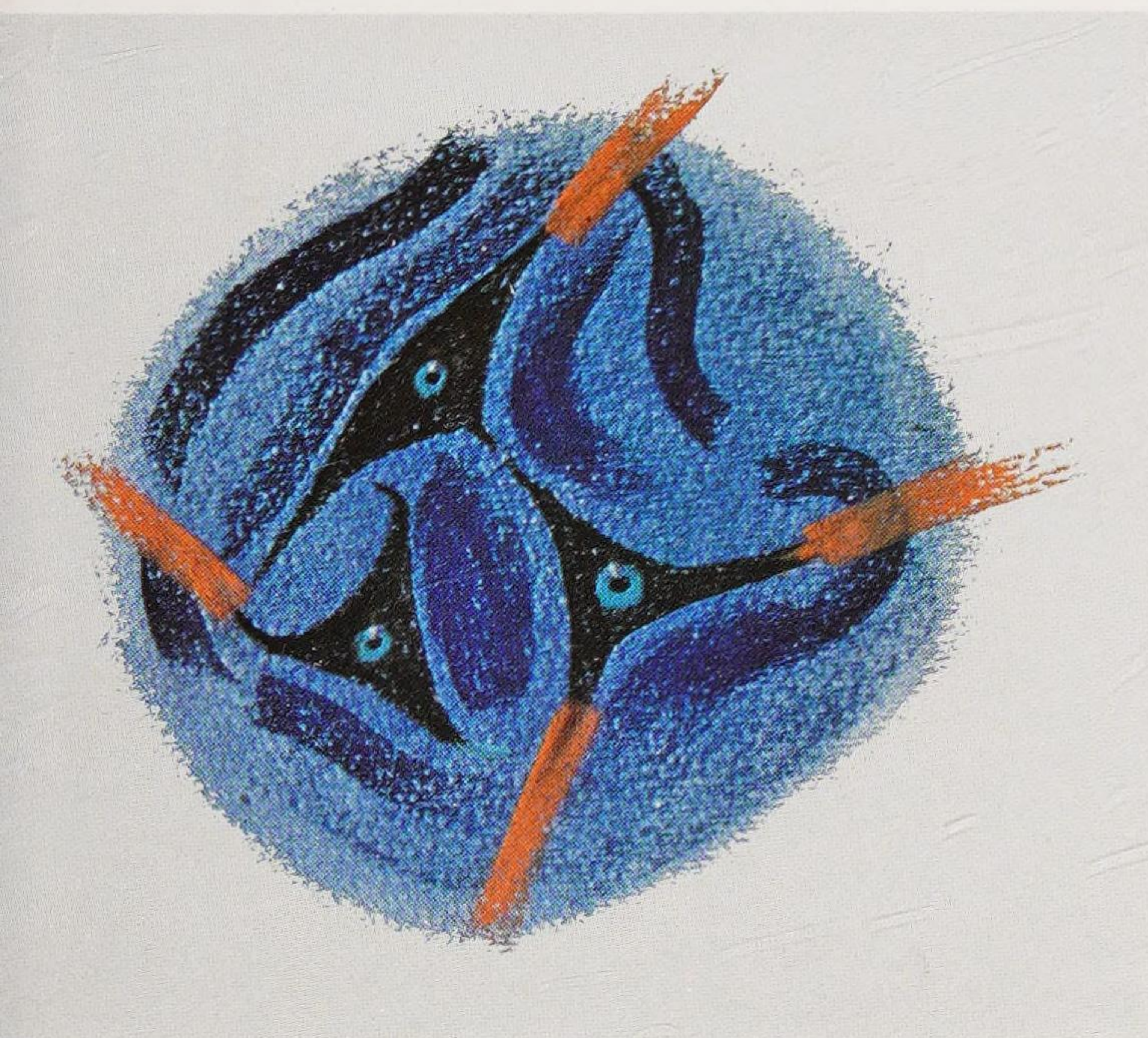






**Plate III** Depiction of an hallucinatory experience, by Yando, untitled, oil, 1970.



**Plate IV** Depiction of an hallucinatory experience, by Yando, untitled, oil, 1971–1972.





**Plate V** Depiction of an hallucinatory experience, by Yando, untitled, oil, 1970.



**Plate VI** Isaac Abrams, *Magician's Night*, oil. (Used with permission of Isaac Abrams and Stanley Krippner.)





**Plate VII** Depiction of an hallucinatory experience, by Yando, untitled, oil, 1971.



**Plate VIII** Depiction of an hallucinatory experience, by Yando, untitled, oil, 1971–1974.





Plate IX LSD-induced visual imagery. (By permission of Oscar Janiger.)



Plate X Deerleeb seen at two different times under LSD treatment. (By permission of Oscar Janiger.)



**Plate XI** (*right*) Dion Wright, example of LSD-induced visual imagery. (By permission of Stanley Krippner.)



**Plate XII** (*below*) Angelo Miranda, *Angel of Death*—dimethyltryptamine-induced visual image. (By permission of Angelo Miranda and Stanley Krippner.)





The idea is hardly original. In 1813 Ferriar wrote an essay on apparitions in which he claimed that formed hallucinations consisted of retrieved memory images:

From recalling images by an art of memory, the transition is direct to beholding spectral objects, which have been floating in the imagination. Yet, even in the most frantic assemblage of this nature, no novelty appears. The Spectre may be larger or smaller; it may be compounded of the parts of different animals; but it is always framed from the recollection of familiar though discordant images (p. 100).

According to Boismont (1853), "the involuntary exercise of memory and imagination" together with internal excitation of sensory systems and suspension of external impressions, results in the production of hallucinations. Similarly, Parish (1897) discussed hallucinations as strictly images of the memory and imagination:

The content of a fallacious perception [hallucination] depends primarily on the past experience of the individual. Only what has passed in at the portals of sense can be reproduced. The neural elements which attain to activity may indeed be associated in the most unfamiliar and bizarre combinations, but they can be called into play only in the way to which they have been predisposed by former sensory stimuli (p. 185).

Studying visual hallucinations occurring in association with tumors compressing the optic nerves and chiasm, Weinberger and Grant (1940) concluded that hallucinations can arise from excitation of any level of the visual system, but "they are the result of the total integrative activities of the mind, which fuse memory, affectural associations and previous visual experience with simple sensory presentations to create an image" (p. 198). Even the visual imagery of daydreams is considered to be chiefly memories and stored fantasy material, although memory sequences are regarded as the easiest to maintain and retrieve (Singer, 1966).

In discussing drug-induced hallucinations, Anstie (1865) described hashish, alcohol, chloroform, and opium as producing "involuntary reminiscence," a class of mental phenomena characterized by retrieved memories: "Alcohol, taken in poisonous doses, not infrequently recalls to the mind circumstances and ideas long since forgotten" (p. 174). In discussing hypnagogic and hypnopompic hallucinations, Ahlenstiel and Kauffmann (1953) described how geometric images (e.g., lines, cones, spirals) are *released* from the mind and lead to concrete complex images through direct projection of pictures onto the geometric structure. These authors claimed that mescaline, *Cannabis*, and morphine were effective agents in producing this phenomenon. Leuner (1962) wrote of a similar geometric screen in the visual field of subjects in mescaline and LSD states. He believed that psychodynamic principles caused certain images to be retrieved from a person's past and *released* onto the screen. More recently, Jarvik (1970) proposed that hallucinations are a memory defect characterized by uninhibited retrieval and that one way in which hallucinogens work is by impairing short-term memory and inducing "vicarious retrieval" of long-term memories.

Memory retrieval forms the central part of many theories of hallucinations. The perceptual release theory (Jackson, 1931; West, 1962) assumes that normal memories are suppressed by a mechanism that gates the flow of information from outside to inside the body. Input of new information inhibits the emergence and awareness of previous perceptions and processed information. If the input is



decreased or impaired and internal arousal is sufficient to permit awareness, the *released* perceptions may be dynamically organized and experienced as hallucinations, dreams, or fantasies. Psychoanalytic theories (e.g., Savage, 1955; Leuner, 1962) postulate a general regression to primitive or childlike thinking, coupled with the emergence of repressed information and memories. Similarly, psychedelic theories (e.g., Leary et al., 1964; Osmond, 1957) postulate that hallucinogens release normally suppressed information and memories in the mind, bringing such components to our attention.

### THE EXPERIENTIAL PROJECTOR MODEL OF HALLUCINATIONS

We propose the following model as a theoretical approach to hallucinations. The model views man as an information-processing system whose output can be described as projections of experience in the form of images, dreams, and hallucinations.

As an information-processing system, man is capable of executing several processes by which sensory input is transformed, reduced, elaborated, stored, retrieved, and used. These processes are generally defined as cognition (Neisser, 1967). That cognitive process by which man receives or extracts information about the internal and/or external environment is referred to as "perception." As information is acquired through experience and becomes part of one's storage of facts, learning occurs. When information is manipulated, as in remembering or problem-solving, the thinking process is said to take place.

In waking consciousness, thinking involves images or representations of a sensation or perception without adequate sensory input (Holt, 1964). Images may appear to represent a perception in any sensory modality and can be considered to be pictures to the extent that "they portray things located at a lower level of abstractness than they are themselves. They do their work by grasping and rendering some relevant qualities—shape, color, movement—of the objects or activities they depict" (Arnheim, 1969, p. 137). The picture metaphor is somewhat misleading, however, since images are more a description than a replica of information. Indeed, Pylyshyn (1973) has argued that these mental images are essentially conceptual and propositional rather than sensory or pictorial because they often contain abstract aspects that are the result of (not inputs to) perceptual processes. Moreover, image formation is generally considered to be a constructive process in that man not only retrieves stored information but carries out new activities such as forming new representations (Neisser, 1972). The propositional and constructive aspects of mental imagery can be illustrated by a simple exercise. Recall the last time you went swimming in the ocean. Now ask yourself if this memory includes a picture of yourself running along the beach or moving about in the water. Such a picture is entirely fictitious, but memory images often include fleeting pictures of oneself. Similarly, subjects in our drug experiments often reported such equally improbable elements in imagery as aerial perspectives and underwater views. It has not been experimentally established where such constructions occur, but contributions are probably made in the encoding, storage, and retrieval stages of the memory process (cf. Paivio, 1972).

When the sensory input that would normally give rise to perceptions is absent, man is either thinking, imagining, dreaming, or hallucinating. These quasi-perceptions are forms of mental imagery that lie on a continuum of intensity of



vividness, thought images being the least vivid and images of hallucinations being the most vivid. The transition from one form of imagery to another along this continuum depends on the arousal state; when arousal is low, there is still a baseline amount of spontaneous firings by cortical cells in normal waking behavior. This activity is suppressed and inhibited from entering into conscious awareness whenever one is asleep or new information is being scanned and processed. However, some introspection or thinking can retrieve the results of these firings, and they are presented as baseline imagery data. The information is projected in the mind's eye (or mind's ear or some other sense organ) and reflects elements of physical structures (e.g., entoptic phenomena, symmetrical organization, and experiences (e.g., recent memories). With low arousal, such experiential projections are weak thought images. When arousal is increased, however, retrieval of information by this system is more successfully obtained (Goldstein and Nelsen, 1973). The information may now appear to be more vividly projected and may contain increasing amounts of complex imagination and fantasy imagery. When arousal is further increased, information may appear to be projected on a sensory field outside the body, especially if other sensory inputs are reduced (e.g., closed eyes, dim light, sensory deprivation). In our drug experiments, visual imagery appeared to be projected on a screen in front of the subject's eyes, and it was at this stage that the transition to hallucinations was achieved. Higher states of arousal may cause information to be projected on and overlaid with the actual stimulus environment, as in the case of hallucinations induced by sensory bombardment (Davenport and Winstead, 1972) or high doses of hallucinogens.

Thus hallucinations occur when imagery is projected outside the observer and is viewed as separate from the projector. The screen contributes very little to the imagery except to provide a locus for its projection; most if not all organization resides in the projector. The observer may feel detached from the projection, a state similar to the breakoff phenomenon experienced by solitary pilots and astronauts who find themselves observing their craft from the outside. The observer's experience of these projections—the sensory fields, emotions, thoughts, and images—make up consciousness.

This conceptualization of hallucinations as experiential projections began more than 130 years ago with Moreau's experiments on hashish. The subsequent inquiry into drug-induced hallucinations has helped to clarify the phenomenology and to suggest methods for further experimental analysis. The investigation of imagery constants suggests possible mechanisms of action, and the emergence of memory imagery reveals itself as man's projection of experiences. Perhaps the time has now come for investigation into even more dramatic aspects of hallucinations, such as the experience of the projector itself as it projects experiences. It will be none too soon, for as Moreau's fellow "hachischin" Baudelaire noted in 1857

"It is time to set aside all this jugglery, all those great marionettes, born of the dreams of childish minds. There are more serious things for us to speak of, are there not?—the changes that occur in human feelings, and, in a word, the 'morality' of hashish" (p. 63).

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